METHODS AND RESULTS

In developing the population identification and classification system that reflects the persistence, isolation, and independence of populations of Oregon Coast coho salmon, we sought an approach that had three desirable characteristics: consistency, reproducibility, and transparency. **Consistency** means that the same approach can be applied across ESUs over a broad geographic area, and lead to comparable results in different areas. **Reproducibility** means that conclusions are predictable; in other words, another group of scientists could apply the same methods to the same information and reach essentially the same result. **Transparency** means that methods are reasonably simple and understandable, so that non-specialists can understand the logical connection between information and conclusions. We chose a rule-based approach that we believe meets these criteria.

Criteria for Identifying the Distribution of Historical Populations

The task of identifying historical coho salmon populations within the Oregon Coast Coho Salmon ESU is challenging, because anthropogenic factors such as hatchery operations, stock transfers, harvest effects, and habitat destruction and degradation have significantly influenced the population structure and interactions we observe today. There are no extant populations unaffected by these anthropogenic factors to provide information regarding historical population structure and number. Information about historical abundance and distribution of fish is available only for a few large basins. We have no alternative, therefore, but to examine a suite of characteristics of modern populations and their watersheds in our effort to identify the selective and isolating factors that may have lead to demographically independent historical populations. The factors we have considered include 1) historical use of habitat; 2) geographical isolation; 3) biological characteristics of populations; and 4) ecological characteristics of river, stream, and lake watersheds. This information was considered across the coastal river, stream, and lake basins that may have historically supported coho salmon (Fig. 3).

Documented Historical Use

The extent of historical use of Oregon Coast coho salmon habitat is not very different from the extent of present use in most basins within the ESU (Fig. 4). There are areas, such as the Smith River (Fig. 5) that have had a major barrier removed. There are also new barriers that restrict access to historical habitat. However, large areas of lowland habitat have been cut off or restricted from access by dikes, tidegates, and other hydrologic changes. Therefore, the extent of Oregon Coast coho salmon use does not show much restriction, but what is not shown is the loss of very significant areas that were historically the core of the populations. Because of these changes, the core of many Oregon Coast coho populations have subsequently persisted only in more marginal, less productive areas (IMST 2002).
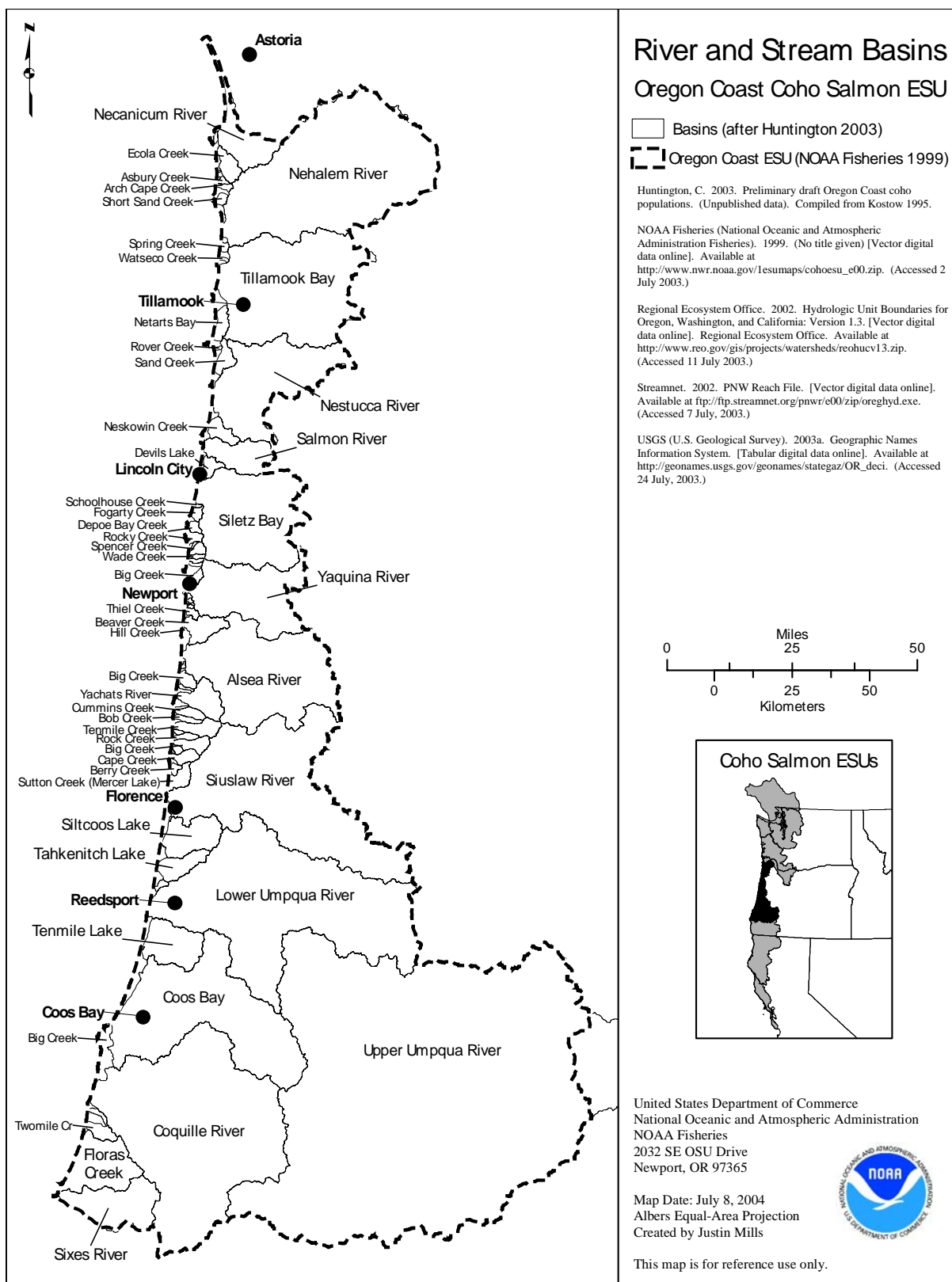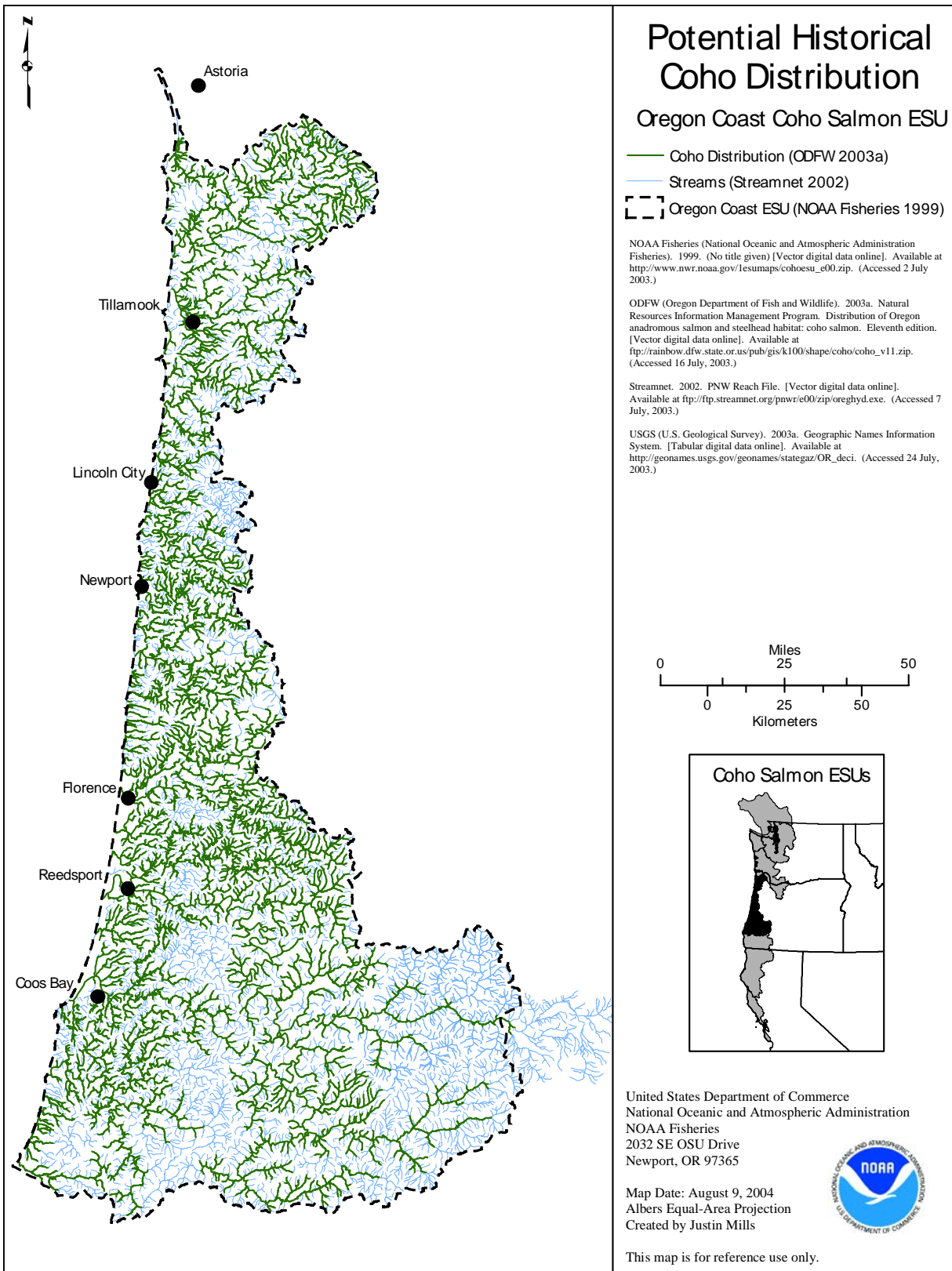
River and Stream Basins

Oregon Coast Coho Salmon ESU

□ Basins (after Huntington 2003)

┌─┐ Oregon Coast ESU (NOAA Fisheries 1999)

Huntington, C. 2003. Preliminary draft Oregon Coast coho populations. (Unpublished data). Compiled from Kostow 1995.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. (No title given) [Vector digital data online]. Available at http://www.nwr.noaa.gov/1esumaps/cohoesu_e00.zip. (Accessed 2 July 2003.)

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USGS (U.S. Geological Survey). 2003a. Geographic Names Information System. [Tabular digital data online]. Available at http://geonames.usgs.gov/geonames/stategaz/OR_deci. (Accessed 24 July, 2003.)

Miles
0   25   50

0   25   50
Kilometers

Coho Salmon ESUs

N

Astoria

Necanicum River

Ecola Creek

Asbury Creek
Arch Cape Creek
Short Sand Creek

Nehalem River

Spring Creek
Watseco Creek

Tillamook Bay

Tillamook

Netarts Bay

Rover Creek
Sand Creek

Nestucca River

Neskowin Creek

Salmon River

Devils Lake

Lincoln City

Schoolhouse Creek
Fogarty Creek
Depoe Bay Creek
Rocky Creek
Spencer Creek
Wade Creek
Big Creek

Siletz Bay

Yaquina River

Newport

Thiel Creek
Beaver Creek
Hill Creek

Big Creek

Alsea River

Yachats River
Cummins Creek
Bob Creek
Tenmile Creek
Rock Creek
Big Creek
Cape Creek
Berry Creek
Sutton Creek (Mercer Lake)

Siuslaw River

Florence

Siltcoos Lake

Tahkenitch Lake

Lower Umpqua River

Reedsport

Tenmile Lake

Coos Bay

Coos Bay

Big Creek

Upper Umpqua River

Twomile Cr

Floras Creek

Coquille River

Sixes River

United States Department of Commerce
National Oceanic and Atmospheric Administration
NOAA Fisheries
2032 SE OSU Drive
Newport, OR 97365

Map Date: July 8, 2004
Albers Equal-Area Projection
Created by Justin Mills

This map is for reference use only.

Figure 3.   River and stream basins in the Oregon Coast Coho Salmon ESU.

Potential Historical Coho Distribution

Oregon Coast Coho Salmon ESU

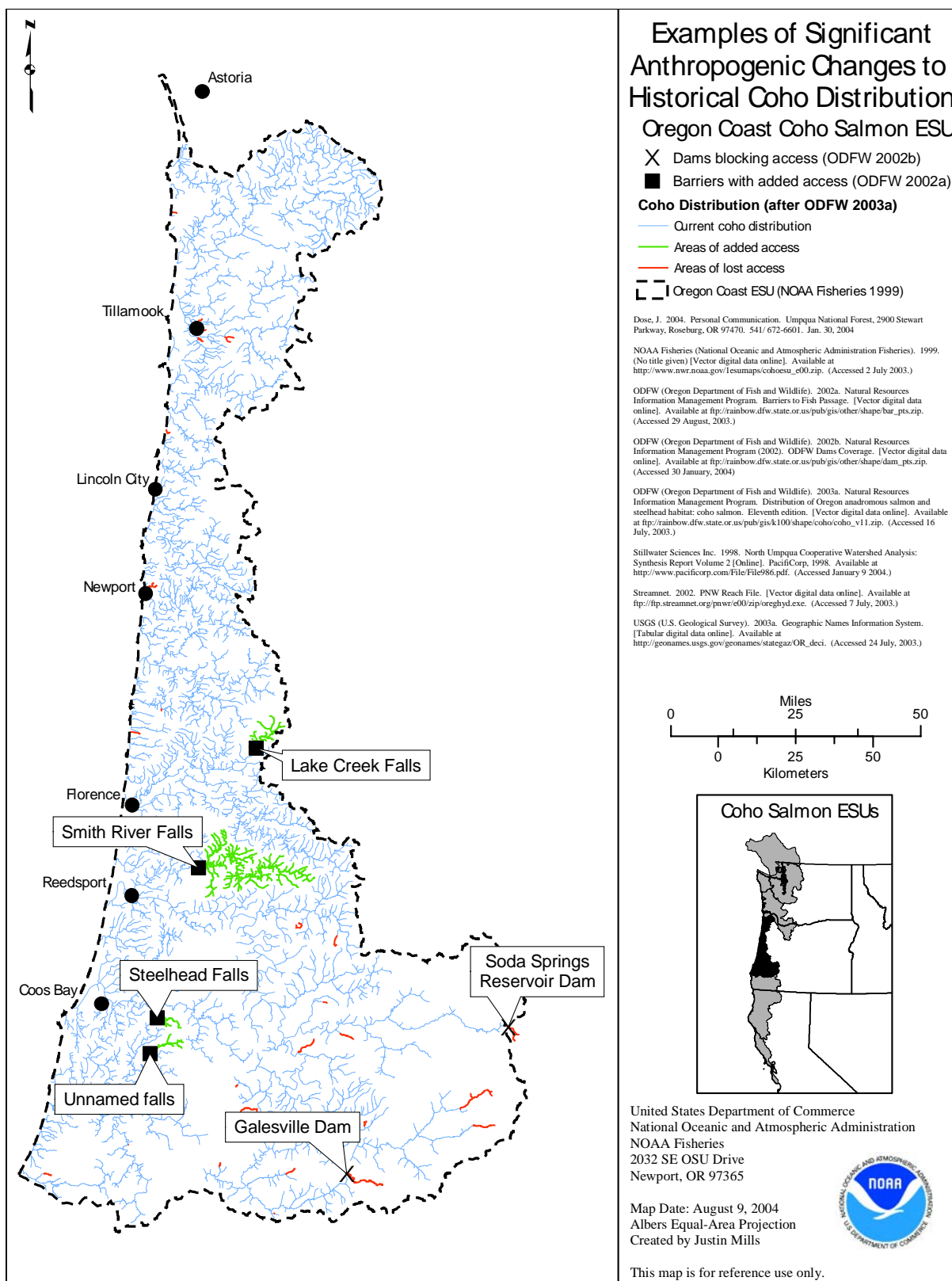— Coho Distribution (ODFW 2003a)

— Streams (Streamnet 2002)

⌐ ¬ Oregon Coast ESU (NOAA Fisheries 1999)

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. (No title given) [Vector digital data online]. Available at http://www.nwr.noaa.gov/1esumaps/cohoesu_e00.zip. (Accessed 2 July 2003.)

ODFW (Oregon Department of Fish and Wildlife). 2003a. Natural Resources Information Management Program. Distribution of Oregon anadromous salmon and steelhead habitat: coho salmon. Eleventh edition. [Vector digital data online]. Available at ftp://rainbow.dfw.state.or.us/pub/gis/k100/shape/coho/coho_v11.zip. (Accessed 16 July, 2003.)

Streamnet. 2002. PNW Reach File. [Vector digital data online]. Available at ftp://ftp.streamnet.org/pnwr/e00/zip/oreghyd.exe. (Accessed 7 July, 2003.)

USGS (U.S. Geological Survey). 2003a. Geographic Names Information System. [Tabular digital data online]. Available at http://geonames.usgs.gov/geonames/stategaz/OR_deci. (Accessed 24 July, 2003.)

Astoria

Tillamook

Lincoln City

Newport

Florence

Reedsport

Coos Bay

Miles
0   25   50

0   25   50
Kilometers

Coho Salmon ESUs

United States Department of Commerce
National Oceanic and Atmospheric Administration
NOAA Fisheries
2032 SE OSU Drive
Newport, OR 97365

Map Date: August 9, 2004
Albers Equal-Area Projection
Created by Justin Mills

This map is for reference use only.

Figure 4.   Potential historical coho salmon distribution in the Oregon Coast Coho Salmon ESU.

Examples of Significant Anthropogenic Changes to Historical Coho Distribution

Oregon Coast Coho Salmon ESU

X — Dams blocking access (ODFW 2002b)
■ — Barriers with added access (ODFW 2002a)

Coho Distribution (after ODFW 2003a)
— Current coho distribution
— Areas of added access
— Areas of lost access
⌐ ¬ Oregon Coast ESU (NOAA Fisheries 1999)

Dose, J. 2004. Personal Communication. Umpqua National Forest, 2900 Stewart Parkway, Roseburg, OR 97470. 541/ 672-6601. Jan. 30, 2004

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. (No title given) [Vector digital data online]. Available at http://www.nwr.noaa.gov/1esumaps/cohoesu_e00.zip. (Accessed 2 July 2003.)

ODFW (Oregon Department of Fish and Wildlife). 2002a. Natural Resources Information Management Program. Barriers to Fish Passage. [Vector digital data online]. Available at ftp://rainbow.dfw.state.or.us/pub/gis/other/shape/bar_pts.zip. (Accessed 29 August, 2003.)

ODFW (Oregon Department of Fish and Wildlife). 2002b. Natural Resources Information Management Program (2002). ODFW Dams Coverage. [Vector digital data online]. Available at ftp://rainbow.dfw.state.or.us/pub/gis/other/shape/dam_pts.zip. (Accessed 30 January, 2004)

ODFW (Oregon Department of Fish and Wildlife). 2003a. Natural Resources Information Management Program. Distribution of Oregon anadromous salmon and steelhead habitat: coho salmon. Eleventh edition. [Vector digital data online]. Available at ftp://rainbow.dfw.state.or.us/pub/gis/k100/shape/coho/coho_v11.zip. (Accessed 16 July, 2003.)

Stillwater Sciences Inc. 1998. North Umpqua Cooperative Watershed Analysis: Synthesis Report Volume 2 [Online]. PacifiCorp, 1998. Available at http://www.pacificorp.com/File/File986.pdf. (Accessed January 9 2004.)

Streamnet. 2002. PNW Reach File. [Vector digital data online]. Available at ftp://ftp.streamnet.org/pnwr/e00/zip/oreghyd.exe. (Accessed 7 July, 2003.)

USGS (U.S. Geological Survey). 2003a. Geographic Names Information System. [Tabular digital data online]. Available at http://geonames.usgs.gov/geonames/stategaz/OR_deci. (Accessed 24 July, 2003.)

Miles
0   25   50

Kilometers
0   25   50

Coho Salmon ESUs

United States Department of Commerce
National Oceanic and Atmospheric Administration
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Newport, OR 97365

Map Date: August 9, 2004
Albers Equal-Area Projection
Created by Justin Mills

This map is for reference use only.

Figure. 5.   Examples of significant anthropogenic changes to historical coho salmon distribution in the Oregon Coast Coho Salmon ESU.

Geographical Isolation

Geographical isolation is an important factor in the evolution of separate populations within a basin or between basins. The Oregon Coast Coho Salmon ESU, in general, is made up of relatively small basins (Fig. 3). The exception to that general rule is the Umpqua Basin, which is quite large and drains areas of very different vegetation, geology, and distance from the marine influence. Table 1 lists the sizes of the basins that supported what we believe were the historical coho populations on the Oregon Coast and the miles of coho stream miles found within them.

The distance between saltwater entry points of each basin may have a significant effect on the degree of migration among populations. Table 2 shows the locations of the basins and the distances between each successive basin. Some populations may be significantly affected by migrants from larger, or more productive systems. Long-term viability as a population may be affected by the distance from these larger or more productive systems.

Biological Characteristics

The first step in the process of identifying historical population patterns in the Oregon Coast Coho Salmon ESU, was to consider several types of biological evidence. We examined life history traits for naturally spawning coho salmon populations, including smolt size and outmigration timing, age at spawning, river entry and spawn timing, ocean migration patterns based on marine coded-wire-tag (CWT) recoveries, homing fidelity, and genetics. The primary objective of this analysis was to discover patterns in these traits that might indicate how historical populations were structured. Because these traits are believed to have both genetic and environmental bases, similarities among populations could indicate either shared genetic heritage or similar responses to shared environmental conditions.

Several factors make compiling and comparing life history trait information on a basin scale more difficult. First, these traits vary greatly over time and space, presumably due in large part to the highly variable environment. Fish examined in different years or from different locations or habitats within a basin may display different life history characteristics, making it difficult to estimate values that characterize historical or basin-wide populations. Because traits also vary greatly from year to year, study results may be sensitive to the period over which they were conducted. For example, measurements of many life history traits for Oregon coho salmon during the 1983 El Niño were very different from those in the years before and after that event (Johnson 1988). A second factor that has confounded our analysis is the lack of information on life history traits, especially the lack of long-term data sets, from most naturally spawning populations. A third complication is that anthropogenic activities such as land-use practices (Hartman et al. 1984, Holtby 1987) and artificial propagation (Steward and Bjornn 1990, Flagg et al. 1995) may alter life history traits. To help limit this bias, life history trait comparisons in this document have focused on naturally spawning populations. However, because of the practice of releasing hatchery fry and smolts in widespread locations, often outside the basin where the parents originated, many studies of naturally spawning populations probably include first- or second-generation hatchery fish. Information on life history traits from hatchery populations was used only when there was insufficient information available from naturally spawning populations, as in the case of ocean migration patterns. As with environmental

Table 1. Basin areas with stream lengths (1:100,000 scale dataset, Streamnet 2003).

Name	Approx. Stream Miles	Approx. Stream km	Acres	Hectares
Necanicum R.	93	150	53,320	21,578
Indian Cr.	1	2	262	106
Canyon Cr.	2	4	1,127	456
Ecola Cr.	19	30	13,538	5,479
Red Rock Cr.	1	2	149	60
Austin Cr.	1	2	203	82
Asbury Cr.	4	6	1,574	637
Rock Cr.	6	10	3,648	1,476
Arch Cape Cr.	3	5	2,317	938
Short Sand Cr.	6	10	2,950	1,194
Nehalem R.	932	1,502	545,738	220,853
Spring Cr.	4	6	1,874	758
Watseco Cr.	2	4	845	342
Tillamook Bay	622	1,002	358,830	145,214
Netarts Bay	17	27	9,705	3,927
Rover Cr.	2	3	634	257
Sand Cr.	20	32	10,825	4,381
Nestucca R.	381	613	204,119	82,605
Neskowin Cr.	24	38	12,355	5,000
Salmon R.	104	168	47,742	19,321
Devils Lake	20	31	7,799	3,156
Siletz R.	548	882	235,531	95,316
Schoolhouse Cr.	2	3	743	301
Fogarty Cr.	8	12	3,324	1,345
Depoe Bay Cr.	8	12	2,985	1,208
Rocky Cr.	8	13	5,047	2,043
Johnson Cr. (near Siletz)	2	4	712	288
Spencer Cr.	8	13	3,807	1,541
Wade Cr.	4	7	1,709	692
Coal Cr.	4	6	1,527	618
Moolack Cr.	3	6	1,311	530
Big Cr. (near Yaquina)	8	13	3,429	1,388
Yaquina R.	351	566	160,658	65,016
Henderson Cr.	2	3	604	244
Grant Cr.	2	3	366	148
Moore Cr.	2	3	554	224
Thiel Cr.	6	10	2,767	1,120
Beaver Cr.	42	68	21,532	8,714

Table 1 continued. Basin areas with stream lengths (1:100,000 scale dataset, Streamnet 2003).

| Name | Basin Sizes | | | |
	Approx. Stream Miles	Approx. Stream km	Acres	Hectares
Alsea R.	530	854	301,778	122,126
Little Cr.	1	2	646	262
Big Cr. (near Alsea)	14	22	5,740	2,323
Vingie Cr.	4	6	1,264	511
Yachats R.	59	94	27,845	11,268
Gwynn Cr.	2	4	800	324
Cummins Cr.	11	17	6,282	2,542
Bob Cr.	6	10	3,669	1,485
Tenmile Cr.	24	38	14,963	6,055
Squaw Cr.	3	4	1,086	439
Big Cr. (near Siuslaw)	17	28	10,125	4,097
China Cr.	6	9	2,128	861
Blowout Cr.	2	3	290	118
Cape Cr.	15	24	7,340	2,971
Berry Cr.	6	9	2,442	988
Sutton Cr. (near Mercer Lake)	18	29	10,692	4,327
Siuslaw R.	916	1,474	496,047	200,744
Siltcoos R. (Lake)	84	135	48,632	19,681
Tahkenitch Lake	39	63	23,276	9,420
Threemile Cr.	5	8	2,105	852
Umpqua R. (Total)	4,611	7,424	2,998,976	1,213,647
Lower Umpqua R.	1,218	1,961	640,914	259,370
Upper Umpqua R.	3,393	5,464	2,358,062	954,278
Tenmile Lake	99	159	57,569	23,297
Coos Bay	760	1,223	384,393	155,559
Coquille R.	1,222	1,968	676,342	273,707
Johnson Cr. (near Coquille)	6	9	2,656	1,075
Twomile Cr.	24	38	9,704	3,927
Floras Cr.	133	215	81,414	32,947
Sixes R.	130	209	85,832	34,735

Table 2.   Locations of river mouths for basins along the Oregon Coast (Kilgour 2003)[1].

Basin Name	Latitude	Longitude	Distance (km) from Columbia River
Columbia	46.244	124.057	0.0
Necanicum	46.012	123.926	27.7
Indian	45.9307	123.9781	37.6
Canyon	45.9304	123.9779	37.6
Ecola	45.8993	123.9625	41.2
Red Rock	45.845	123.961	47.3
Austin	45.819	123.964	50.2
Asbury	45.815	123.962	50.6
Arch Cape	45.804	123.966	51.9
Short Sands	45.76	123.963	56.8
Nehalem	45.658	123.933	68.4
Spring	45.62	123.937	72.6
Watseco	45.589	123.984	77.6
Tillamook	45.488	123.901	90.5
Netarts	45.403	123.944	100.6
Rover	45.328	123.967	109.1
Sand	45.29	123.937	113.9
Nestucca	45.184	123.956	125.8
Neskowin	45.1	123.986	135.4
Salmon	45.047	124.005	141.5
Devils Lake	44.968	124.016	150.3
Siletz	44.904	124.01	157.4
Schoolhouse	44.873	124.041	161.6
Fogarty	44.839	124.053	165.5
Depoe	44.806	124.058	169.2
Rocky	44.779	124.071	172.4
Johnson	44.738	124.059	177.0
Spencer	44.729	124.059	178.0
Wade	44.716	124.06	179.5
Coal	44.708	124.061	180.4
Moolack	44.703	124.063	180.9
Big Creek (near Yaquina)	44.659	124.058	185.8
Yaquina	44.613	124.017	191.9
Henderson	44.589	124.068	196.7
Grant	44.581	124.068	197.6
Moore	44.572	124.069	198.6
Thiel	44.565	124.07	199.4
Beaver	44.524	124.075	204.0

[1] Columbia and Elk rivers are included to locate the ESU boundary. Tributaries to Tillamook Bay are assumed to harbor a single population.

Table 2 continued. Locations of river mouths for basins along the Oregon Coast (Kilgour 2003)[1].

Basin Name	Latitude	Longitude	Distance (km) from Columbia River
Alsea	44.423	124.08	215.2
Little	44.393	124.088	218.6
Big Creak (near Alsea	44.371	124.088	221.0
Vingie	44.341	124.098	224.5
Yachats	44.309	124.107	228.1
Gwynn	44.271	124.11	232.3
Cummins	44.266	124.108	232.9
Bob	44.244	124.11	235.3
Tenmile	44.226	124.11	237.3
Squaw	44.2086	124.1133	239.3
Rock	44.183	124.114	242.1
Big Creek (near Suislaw)	44.177	124.114	242.8
China	44.169	124.115	243.7
Blowout	44.157	124.117	245.0
Cape	44.134	124.123	247.6
Berry	44.095	124.122	251.9
Sutton (Lake)	44.06	124.127	255.9
Siuslaw	44.017	124.136	260.7
Siltcoos (Lake)	43.874	124.153	276.6
Tahkenitch (Lake)	43.815	124.165	283.3
Threemile	43.748	124.18	290.8
Umpqua	43.669	124.204	299.8
Tenmile (Lake)	43.562	124.231	311.9
Coos	43.429	124.229	326.6
Coquile	43.124	124.429	364.2
Johnson	43.093	124.431	367.6
Twomile	43.044	124.441	373.1
Floras	42.913	124.496	388.3
Sixes	42.854	124.543	395.9
Elk	42.81	124.533	400.9

[1] Columbia and Elk rivers are included to locate the ESU boundary. Tributaries to Tillamook Bay are assumed to harbor a single population.

variability, the effects of anthropogenic activities may confuse the determination of average life history traits and are difficult to factor out.

Because of these potential sources of variability, data were collected from as many sources as possible to give some indication of average results. We especially sought older data sets to indicate coho salmon population traits prior to the 1960s, when technological advances in hatchery practices made it possible to raise large numbers of salmon to juvenile or smolt stages. The resulting proliferation of hatchery release programs has probably decreased local variability among coho populations (Weitkamp 1995, Ford et al. 2004).

The coho salmon life cycle is summarized in Figure 6. Adult coho salmon begin migrating into coastal streams and rivers with the first freshets in the fall. Spawning begins in November, peaks in December or January, and may continue into March. Wild spawners typically migrate and spawn later than hatchery fish in the same area. Eggs hatch in the spring and fry grow rapidly to parr stage by summer or early fall. Parr then seek out areas protected from high flows and spend a second winter in freshwater before migrating to the ocean as smolts in March through June. About 20% of males mature at age 2 and return to freshwater as "jacks" in the same year they entered the ocean as smolts. The remainder of juveniles rear in the ocean for 18 months and return as 3-year-old adults in the following fall (Lawson et al. 2004).

Smolt size and outmigration timing

Recent data do not suggest any population-based pattern for either smolt outmigration timing (Table 3) or smolt size (Table 4) in modern Oregon Coast coho salmon. Regardless of the basin of origin, peak outmigration timing generally occurs in May, with some runs earlier or later, and with most smolts measuring 90-115 mm (3.5-4.5 in.) fork length.

Smolt outmigration timing and smolt size appear to respond to small-scale habitat variability. Smolts residing in ponds or lakes often have different outmigration timing and are a different size than smolts residing in streams within the same basin (Rodgers et al. 1993, Nielsen 1994). For example, large smolts observed in Tenmile Lakes were thought to have resulted from a productive lake-rearing environment (McGie 1970). Both smolt outmigration timing and size exhibit considerable interannual variation; mean smolt sizes from a single system can vary substantially between years (Table 4), whereas peak outmigration timing can vary by several weeks to a month (Table 3).

Because of their responses to small-scale habitat variability, smolt size and outmigration timing have also been shown to be affected by anthropogenic activities, including habitat degradation (Moring and Lantz 1975) and habitat restoration (Johnson et al. 1993, Rodgers et al. 1993). These factors thoroughly complicate the assessment of any basin-linked pattern that may exist for either trait, because these activities have occurred throughout the range of Oregon Coast coho salmon. Sampling design may also influence reported smolt sizes and outmigration timing. It is impossible to discern the historical patterns of smolt size and outmigration timing from the modern patterns cited here. We are unable to predict the effects of anthropogenic activities on these patterns and from this describe the historical condition. Therefore, these characteristics do not appear to be useful in defining historical populations within the Oregon Coast Coho Salmon ESU.
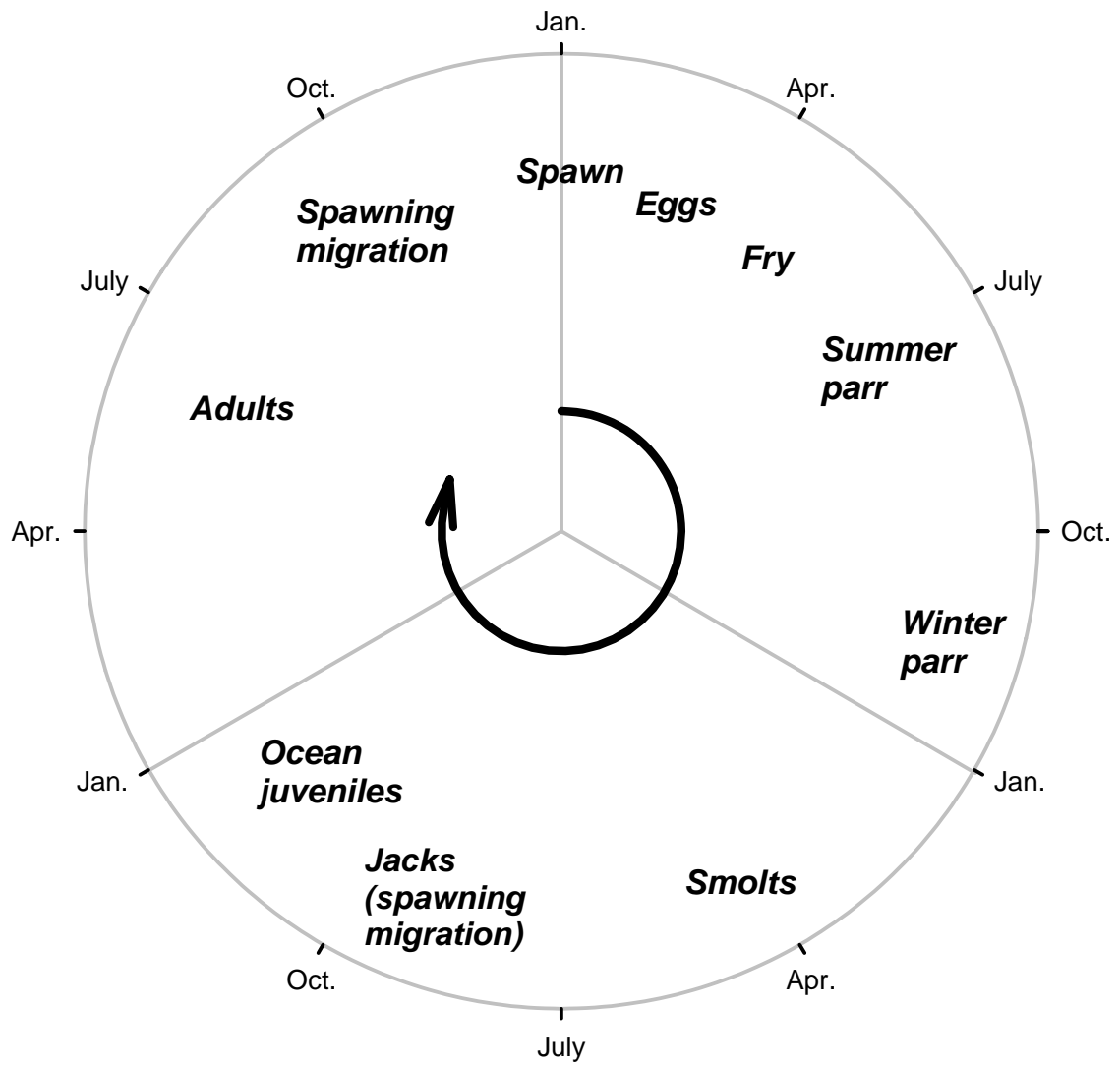
Figure 6.   Life cycle of the coho salmon in Oregon (modified from Lawson et al. 2004).

Table 3.   Oregon Coast coho salmon smolt outmigration peak timing and duration (after Weitkamp 1995).

River (Tributary)	Smolt Outmigration Duration	Peak Smolt Outmigration	Years Covered	Source
Wilson (Spring Cr.)	Feb-June	Apr	1949-58	Skeesick (1970)
Tillamook (Sand Cr.)	mid Mar-mid June	early May	1946-49	Sumner (1953)
Nestucca (East Cr.)		late April	1988-91	Johnson et al. (1993), Rodgers et al. (1993), Weeks (1994)
Nestucca (Moon Cr.)		late April-early May	1988-91	Rodgers et al. (1993)
Salmon		May	1975-76	McGie (1977)
Alsea	Mar-May	Mar-Apr	1959-73	Moring and Lantz (1975)
Alsea (Lobster Cr.)	Feb-June	late Mar-early Apr	1988-93	Johnson et al. (1993), Rodgers et al. (1993), Weeks (1994)
Alsea (Drift Cr.)	Feb-May			Chapman (1965)
Alsea (Crooked Cr.)		May	1973-79	Weeks (1994)
Tenmile Cr.		May	1992-93	Johnson et al. (1993), Weeks (1994)
Cummins Cr.		late Apr-early May	1992-93	Johnson et al. (1993), Weeks (1994)
Siuslaw	Feb- June	Mid May	1983	Rodgers et al. (1993)
Siuslaw (Triangle Lake)		early May	1973	Weeks (1994)
Tenmile Lake		mid-May	1970-75	McGie (1970-73, 1975)
Floras Lake		mid-May	1973	Weeks (1994)
Coquille		late Apr-early May	1979	Weeks (1994)
Sixes	Mar-June	early-mid May	1969	Reimers (1971)
Nehalem (N. Fk.)		late April-early May	1998-2002	Solazzi et al. (2003)
Tillamook (LS Fk. Kilchis)		late March-early May	1998-2002	Solazzi et al. (2003)
Tillamook (LN Fk. Wilson)		late April-late May	1998-2002	Solazzi et al. (2003)
Siletz (Mill Cr.)		late April-mid-May	1998-2002	Solazzi et al. (2003)
(Bales Cr.)		late March-mid-May	1998-2002	Solazzi et al. (2003)
Yaquina (Mill Cr.)		late April-early May	1998-2002	Solazzi et al. (2003)
Cascade		mid-late April	1998-2002	Solazzi et al. (2003)
Alsea (UM Lobster)		early April-mid-May	1998-2002	Solazzi et al. (2003)
Alsea (E. Fk. Lobster)		early-late April	1998-2002	Solazzi et al. (2003)
Cummins Cr.		late April-late May	1998-2002	Solazzi et al. (2003)

Table 3, continued. Oregon Coast coho salmon smolt outmigration peak timing and duration (after Weitkamp 1995).

River (Tributary)	Smolt Outmigration Duration	Peak Smolt Outmigration	Years Covered	Source
Tenmile Cr.		late April-early June	1998-2002	Solazzi et al. (2003)
Smith (W. Fk.)		mid April-mid-May	1998-2002	Solazzi et al. (2003)
(Fall Cr.)		early April-mid-May	1998-2002	Solazzi et al. (2003)

Table 4.   Oregon Coast coho salmon smolt sizes (after Weitkamp 1995).

River (Tributary or Location)	Smolt Size Range (mm)	Mean Smolt Size (mm)	Avg. Length at Peak Migration (mm)	Year(s) Covered	Source
Tillamook (Wilson)	**	100		1949-58	Skeesick (1970)
Tillamook (Sand Cr.)	41-184	105-110		1946-49	Sumner (1953)
Nestucca (East Cr.)	**	100		1988-90	Rodgers et al. (1993)
Nestucsca (East Cr.)	**	116		1991-92	Rodgers et al. (1993)
Nestucca (Moon Cr.)	**	97-102		1988-92	Rodgers et al. (1993)
Yaquina	88-160	118		1980	Nicholas et al. (1982)
Alsea (Lobster Cr.)	**	86		1988-91	Rodgers et al. (1993)
Alsea (Lobster Cr.)	**	91		1992-93	Rodgers et al. (1993), Weeks (1994), Johnson et al. (1993) Johnson et al. (1993)
Alsea (E.F.Lobster Cr.)	**	82-83		1988-92	Rodgers et al. (1993)
Alsea (Drift Cr.)	**	80-90		1959-62	Chapman (1965)
Alsea (Deer Cr.)	**	97		1960-73	Knight (1979)
Alsea (Flynn Cr.)	**	95		1960-73	Knight (1979)
Alsea (Needle Cr.)	**	93		1960-73	Knight (1979)
Siuslaw	**	100-107		1983	Rodgers et al. (1987)
Umpqua	**	100		1991	Roper (1994)
Tenmile Lake	**	152		1970-75	McGie (1970-73, 1975)
Sixes	88-150	120		1969	Reimers (1971)
N. Fk. Nehalem	**		101-122	1998-2002	Solazzi et al. (2003)
Tillamook LS Fk. Kilchis	**		99-118	1998-2002	Solazzi et al. (2003)
Tillamook LN Fk. Wilson	**		102-111	1998-2002	Solazzi et al. (2003)
Siletz (Mill)	**		95-117	1998-2002	Solazzi et al. (2003)
Yaquina Bales	**		98-101	1998-2002	Solazzi et al. (2003)
Yaquina Mill	**		122-157	1998-2002	Solazzi et al. (2003)
Alsea Cascade	**		100-140	1998-2002	Solazzi et al. (2003)
Alsea UM Lobster	**		81-98	1998-2002	Solazzi et al. (2003)
Alsea E Fk Lobster	**		77-100	1998-2002	Solazzi et al. (2003)
Cummins	**		105-115	1998-2002	Solazzi et al. (2003)
Tenmile Cr.	**		111-121	1998-2002	Solazzi et al. (2003)
Umpqua (WFk Smith)	**		102-116	1998-2002	Solazzi et al. (2003)
Coos (Fall)	**		100-123	1998-2002	Solazzi et al. (2003)

** No data.

Age at spawning

In the Oregon Coast Coho Salmon ESU, the vast majority of adult fish are 3-year-olds, having spent approximately 18 months in freshwater and 18 months in salt water (Gilbert 1912, Pritchard 1940, Loeffel and Wendler 1968). Exceptions to this pattern are jacks; sexually mature males that return to freshwater to spawn after only 5–7 months in the ocean. A small fraction of adults return at age 4, having spent an extra year in freshwater before spawning (Moring and Lantz 1975).

Drucker (1972) suggested that there is a latitudinal cline in the proportion of jacks in coho salmon populations, with populations in California having more jacks and those in British Columbia having almost none. Although the production of jacks is a heritable trait in coho salmon (Iwamoto et al. 1984), it is also strongly influenced by environmental factors (Silverstein and Hershberger 1992). The proportion of jacks in a given coho salmon population appears to be highly variable through time (Table 5; Zhou 2000), likely as a response of the population to environmental variation.

Some systems have also shown long-term changes in the proportion of jacks produced. The Tenmile Lakes system (Oregon) historically produced large numbers of jacks (Morgan and Henry 1959) but no longer does (Ursitti 1989), presumably because of altered freshwater predation pressures (Reimers et al. 1993). Because of the high level of variability in the relative production of jacks in a population, and its sensitivity to environmental change, the proportion of jacks appeared to be a poor indicator of historical population patterns and was not pursued further.

River entry and spawn timing

In general, river entry and spawn timing show considerable spatial and temporal variability. Most modern Oregon Coast coho salmon enter rivers in October (Mullen 1981a). Spawning occurs from November through January and occasionally into February, depending on the population (Figs. 7a-e). Some coho may spend 1 or 2 months in freshwater before spawning (Flint and Zillges 1980).

Coho salmon river entry timing is influenced by many factors; one of the most important appears to be river flow (Sumner 1953). Coho salmon wait for freshets before entering rivers, so a delay in fall rains delays river entry and spawn timing. Delays in river entry of over a month are not unusual (Eames et al. 1981). Several small Oregon Coast coho salmon systems have sandbars that block their mouths for most of the year except during winter (such as Devils Lake, Sixes River, New River). In these systems, coho and other salmon species are unable to enter the rivers until sufficiently strong freshets breach the sandbars (Sandercock 1991).

These factors make determining and comparing average or peak river entry and spawn timing difficult because of the high spatial and temporal variability exhibited within basins. Compared to normal run times, river entry of some coho salmon populations are exceptionally early or late. It was originally thought that this might be helpful in delineating historical populations. However, the relationship between populations with unusually timed runs is not well understood and exceptional run timing is found in numerous geographical areas.

Table 5.   Coho salmon freshwater harvests and terminal runs in Tahkenitch, Siltcoos, and Tenmile Lakes basins 1960-1999. After Zhou (2000).

Tahkenitch			Siltcoos			Tenmile Lakes		
Run year	**Adult Catch**	**Jack Catch**	**Run year**	**Adult Catch**	**Jack Catch**	**Run year**	**Adult Catch**	**Jack Catch**
1960	28	16	1960	340	104	1960	238	1,127
1961	62	12	1961	620	218	1961	462	537
1962	48	6	1962	500	85	1962	366	435
1963	92	49	1963	867	510	1963	658	2,005
1964	31	7	1964	365	60	1964	258	397
1965	28	9	1965	339	167	1965	238	276
1966	89	29	1966	842	93	1966	638	726
1967	21	16	1967	286	128	1967	195	358
1968	100	23	1968	927	205	1968	706	488
1969	69	73	1969	371	461	1969	254	785
1970	23	11	1970	207	52	1970	910	3,467
1971	53	6	1971	100	16	1971	665	307
1972	19	22	1972	373	255	1972	200	102
1973	30	6	1973	280	82	1973	228	148
1974	8	7	1974	244	326	1974	103	71
1975	4	11	1975	413	107	1975	266	380
1976	4	3	1976	210	50	1976	10	9
1977	11	2	1977	134	37	1977	95	83
1978	3	1	1978	153	25	1978	34	30
1979	0	0	1979	3	0	1979	0	0
1980	0	0	1980	286	52	1980	24	31
1981	8	4	1981	485	178	1981	194	185
1982	0	0	1982	360	96	1982	76	117
1983	0	0	1983	272	316	1983	133	125
1984	123	49	1984	1,091	198	1984	287	120
1985	12	8	1985	236	89	1985	67	50
1986	47	22	1986	398	209	1986	102	60
1987	5	3	1987	121	19	1987	15	9
1988	0	0	1988	358	41	1988	90	60
1989	11	12	1989	184	61	1989	373	452
1990	19	17	1990	202	55	1990	108	58
1991	30	6	1991	248	29	1991	144	44
1992	0	0	1992	85	43	1992	50	53
1993			1993			1993	8	4
1994			1994			1994	95	86
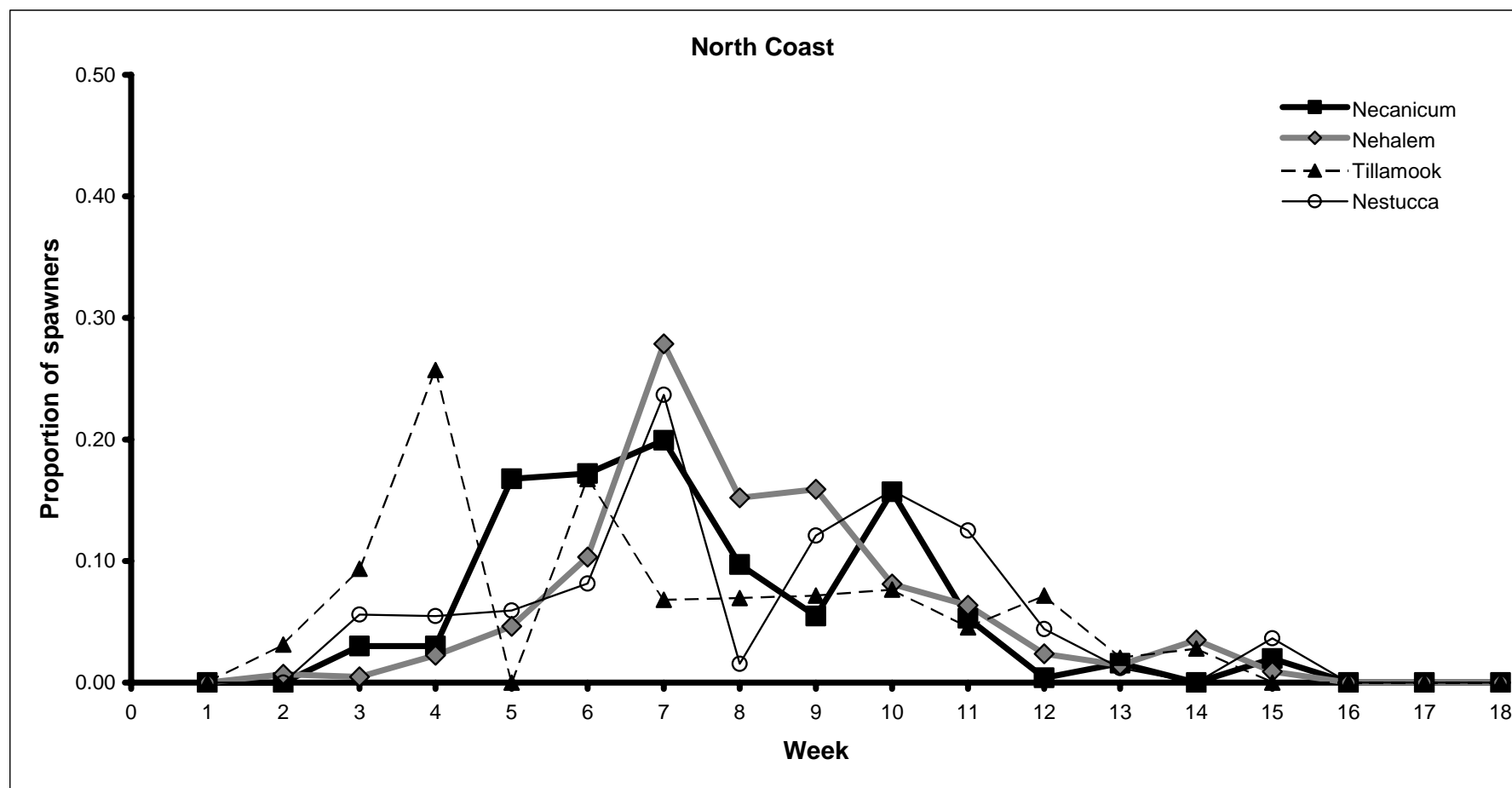
Figure 7a.   2001 North Coast spawn timing for Oregon Coast coho salmon (NOAA 2004)[1].

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[1] To convert weeks to calendar dates: week 1 = Oct. 15-21; week 3 = Oct. 29-Nov. 4; week 7 = Nov. 26-Dec. 2; week 11 = Dec. 24-31; week 16 = Jan. 29-Feb. 4, and; week 18 = Feb. 12-18.
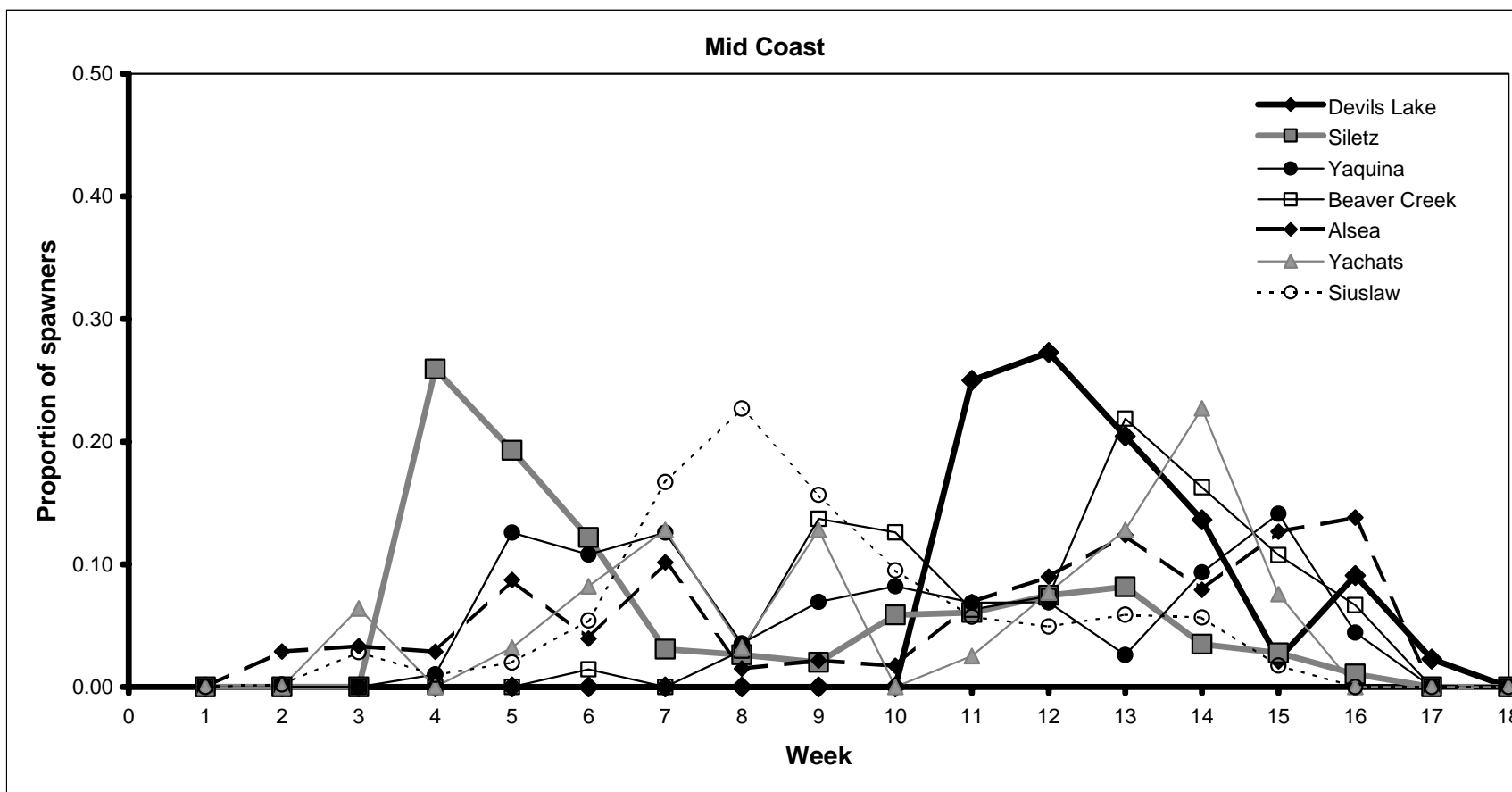
Figure 7b.   2001 Mid-Coast spawn timing for Oregon Coast coho salmon (NOAA 2004)[1].

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[1] To convert weeks to calendar dates: week 1 = Oct. 15-21; week 3 = Oct. 29-Nov. 4; week 7 = Nov. 26-Dec. 2; week 11 = Dec. 24-31; week 16 = Jan. 29-Feb. 4, and; week 18 = Feb. 12-18.
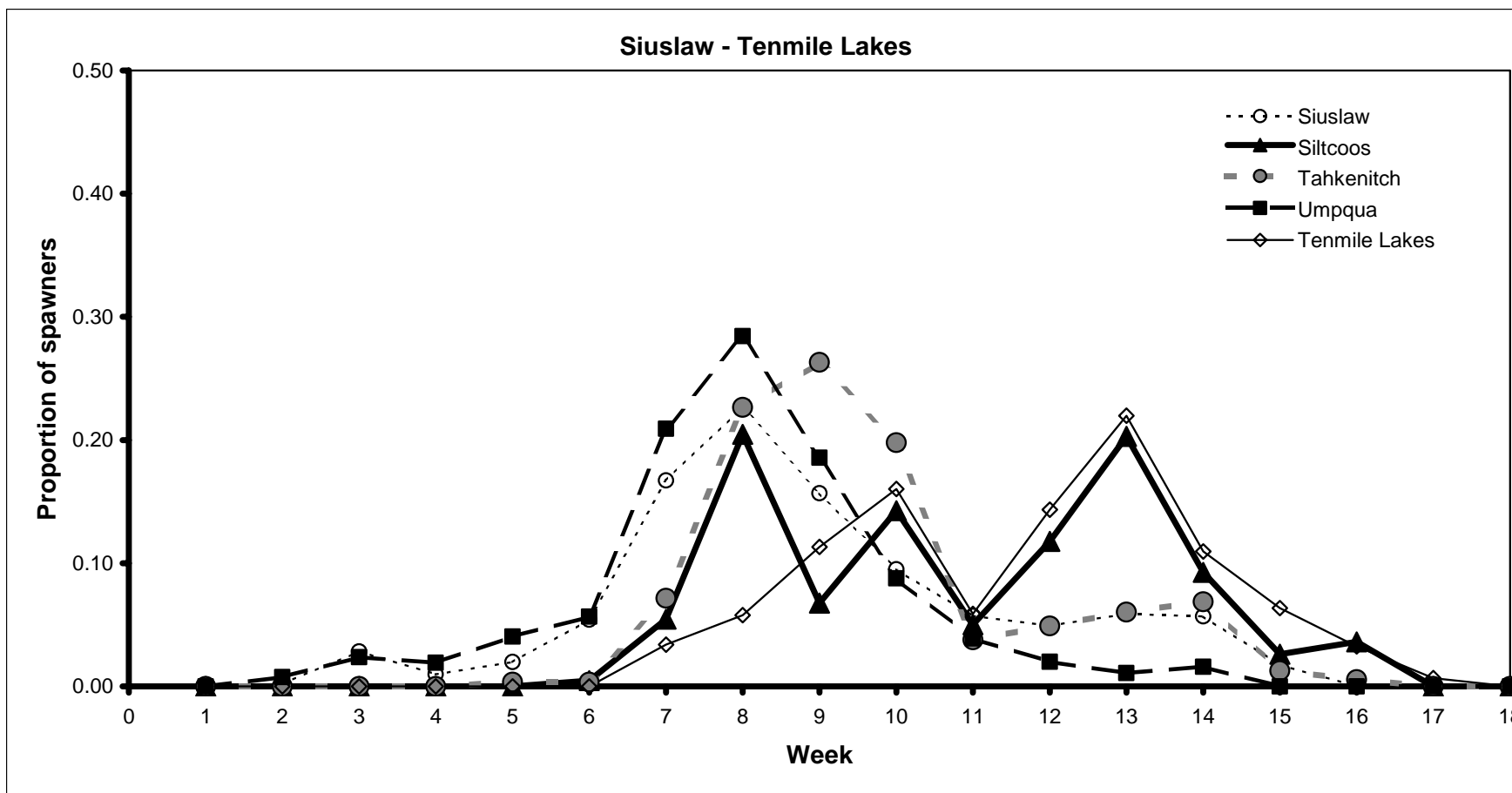
Figure 7c.   2001 Suislaw-Tenmile Lakes spawn timing for Oregon Coast coho salmon (NOAA 2004)[1].

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[1] To convert weeks to calendar dates: week 1 = Oct. 15-21; week 3 = Oct. 29-Nov. 4; week 7 = Nov. 26-Dec. 2; week 11 = Dec. 24-31; week 16 = Jan. 29-Feb. 4, and; week 18 = Feb. 12-18.
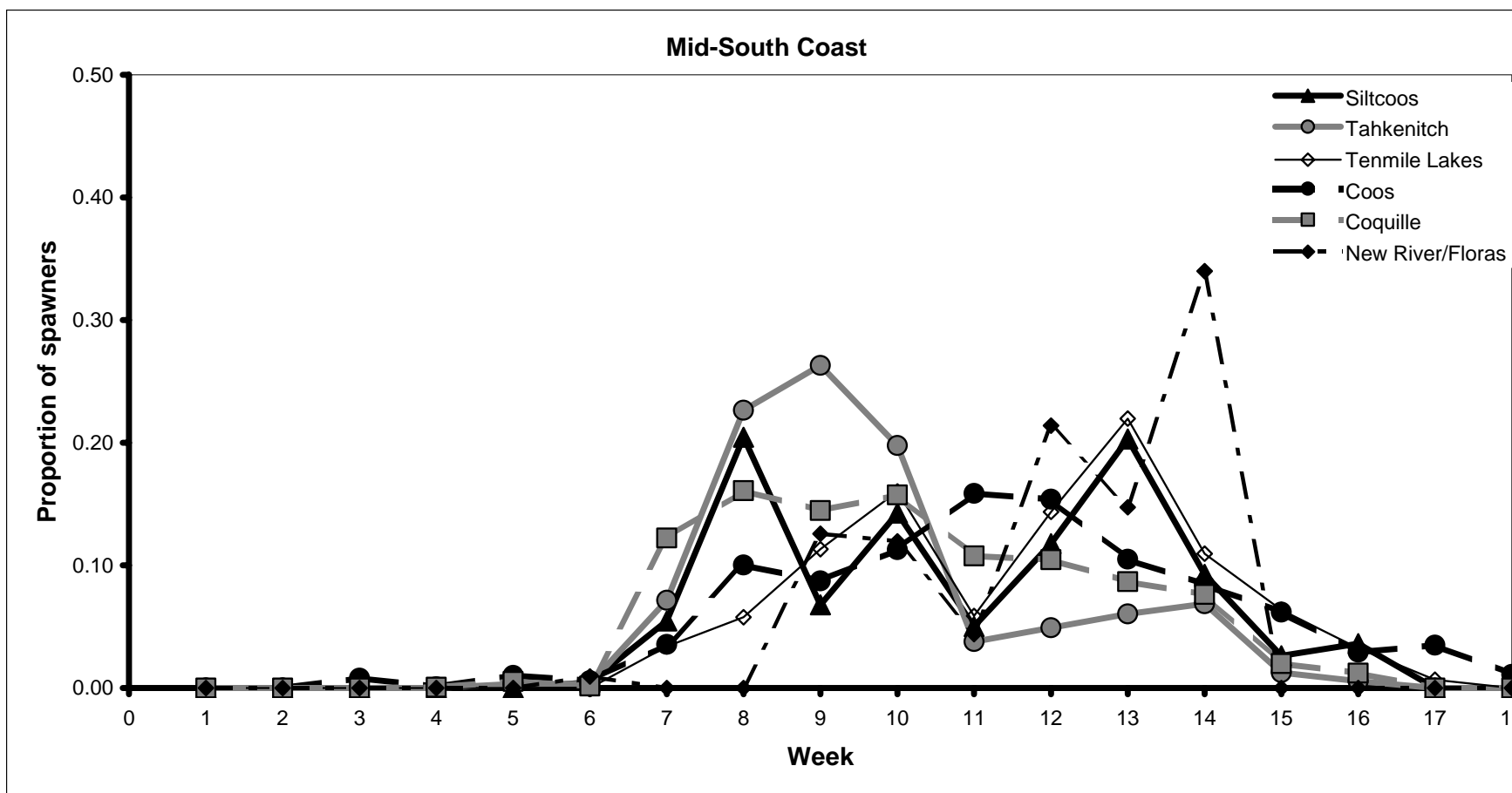
Figure 7d.   2001 Mid-South Coast spawn timing for Oregon Coast coho salmon (NOAA 2004)[1].

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[1] To convert weeks to calendar dates: week 1 = Oct. 15-21; week 3 = Oct. 29-Nov. 4; week 7 = Nov. 26-Dec. 2; week 11 = Dec. 24-31; week 16 = Jan. 29-Feb. 4, and; week 18 = Feb. 12-18.
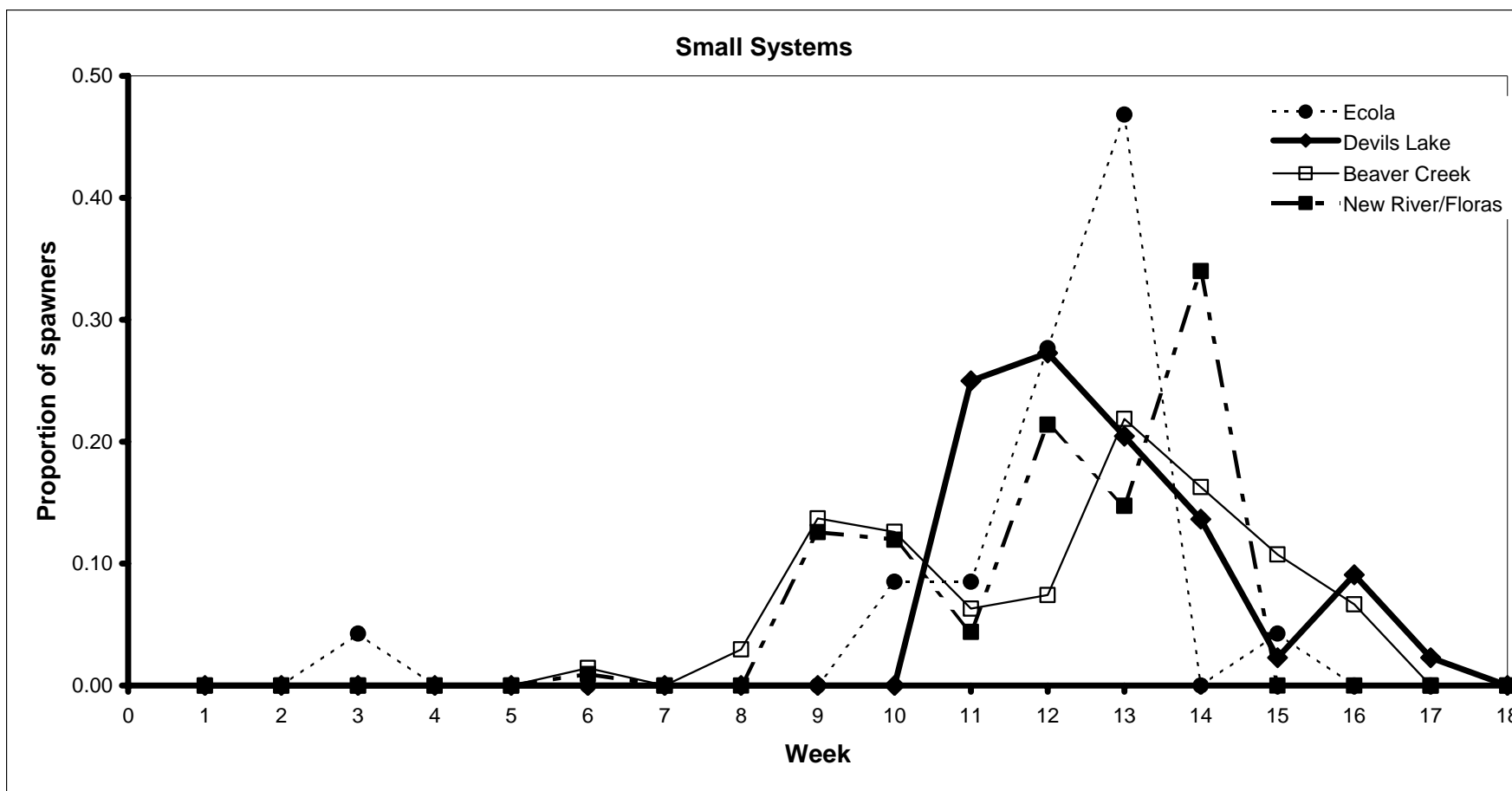
Figure 7e.   2001 Small systems spawn timing for Oregon Coast coho salmon (NOAA 2004)[1].

[1] To convert weeks to calendar dates: week 1 = Oct. 15-21; week 3 = Oct. 29-Nov. 4; week 7 = Nov. 26-Dec. 2; week 11 = Dec. 24-31; week 16 = Jan. 29-Feb. 4, and; week 18 = Feb. 12-18.

Historically, the range of variation might have given clues to population structure in the basins. However, because of the effect of stock transfer and hatchery programs, as well as other anthropogenic effects, it is impossible to discern historical patterns from modern observations. Because there is no evidence to suggest that all runs of a certain type are closely related, we now consider differently timed modern runs to be a component of overall life history diversity within each area and not an indication of historical population structure.

Marine distribution

Coho salmon smolts from the Oregon Coast enter the ocean in the spring and usually encounter a southward-flowing coastal current. Once in the coastal ocean they tend to swim north, but depending on the strength of the currents, may initially be displaced to the south (Pearcy 1992). As juveniles grow larger, swimming speed increases, resulting in a net northward movement. By late summer, juveniles from the coast are distributed off the mouth of the Columbia River and the Washington Coast (Pearcy and Fisher 1988, Brodeur et al. 2004). In the fall, early-maturing males (jacks) return to their natal streams.

Fall and winter distribution of Oregon coastal coho salmon are less well known. Hartt and Dell (1986) report results of tagging experiments conducted from 1956 to 1968. Juvenile salmon in the Gulf of Alaska were tagged at sea and recovered as adults the following year. They estimated that up to 37% of the fish they tagged returned to Oregon and California, with 20% of tags recovered south of the Columbia River. Recent sampling efforts in British Columbia and the Gulf of Alaska confirm the presence of juvenile coho salmon from the Oregon Coast in northern British Columbia (Welch et al. 2004) and the Gulf of Alaska (Weitkamp 2004). However, it doesn't appear that they are as abundant as Hartt and Dell (1986) observed. Pearcy (1992) postulates that ocean conditions may have changed, altering migration patterns. Alternatively, the shift from predominantly wild to predominantly hatchery fish may have affected migration patterns, because the wild fish tend to enter the ocean earlier and migrate further north.

There is a southward migration during the winter or early spring. Maturing fish first appear in ocean salmon fisheries in May off the coast of Northern California, as far south as Monterey (Weitkamp and Neely 2002). There is a northward migration in late spring and summer, with fish arriving in the Coos Bay area in June, and in the ocean off Newport and Tillamook in July. A few adults are caught as far north as Northwest Vancouver Island (Canada), but the majority are caught south of the Columbia River. By August, adults are starting to home to their natal systems, returning to freshwater in September through November.

Coded-wire tags (CWTs) can provide information on marine distribution of specific hatchery populations. They are primarily recovered from marine fisheries or when the salmon return to hatcheries. Consequently, CWT recovery patterns only indicate ocean migration patterns during the last few months of a 1½-year-long migration. Although patterns of movement during earlier stages of ocean migration have been studied (such as Loeffel and Forster 1970, Hartt 1980, Miller et al. 1983, Hartt and Dell 1986, Pearcy and Fisher 1988), the studies are not broad enough in scope to adequately compare early migration patterns for coho salmon released from different areas of the Oregon Coast.

Coded-wire-tag (CWT) recoveries show distinctive differences between regions, as is observed between the SONCC and the Oregon Coast Coho Salmon ESUs (Weitkamp and Neely 2002). Within the Oregon Coast there is a tendency for north-coast fish to be caught in more northerly fisheries, while south-coast fish contribute more heavily to southern fisheries. However, the tendency is not strong enough for us to draw conclusions about neighboring populations within regions, such as between the Yaquina and the Siuslaw rivers. The CWT recovery data provide information at the ESU scale, but are not useful for distinguishing between historical populations.

Genetics

Weitkamp et. al (1995) reviewed the genetics studies available at the time and presented a new analysis of samples collected by NOAA Fisheries. In allozyme studies, coho salmon from the Oregon Coast Coho Salmon ESU consistently showed genetic differences from other groups, including the Columbia River to the north and the Rogue and Klamath rivers to the south (Olin 1984, Solazzi 1986, Hjort and Schreck 1982). One study (Hjort and Schreck 1982) also found that hatchery populations from the north coast of Oregon were distinct from the natural spawners. Studies of DNA patterns concluded there was a unique stock unit south of the Columbia River to Cape Blanco (Currens and Farnsworth 1993, Forbes et al. 1993).

Samples of DNA from California to Alaska (Milner 1993, Johnson et al. 1991) were analyzed for allele frequencies and genetic distances at 6 gene loci (Weitkamp et al. 1995). Cluster analysis identified two overlapping groups on the Oregon Coast: a north-central group (with samples from Alsea, Trask, Siletz, and Nehalem) and a central to south-central group (with samples from the Rogue, Sixes, Eel, Tenmile, New, Coos, Tahkenitch, Alsea, Beaver, Siletz, Salmon, Smith, and Coquille). The Umpqua Basin was in a third group along with Trinity, Rogue, and Elk. The same analysis also grouped Washington Coast and Puget Sound coho salmon separately from Columbia River fish.

Recently, NOAA Fisheries (Ford et al. 2004) analyzed seven microsatellite loci in DNA extracted from coho salmon scales collected from 12 systems on the south-central and central Oregon coast in 2000 and 2001. Additional fin and muscle samples from nearby systems collected between 1991 and 1997 were also used in the analysis. Samples were selected to examine variability within and between three groups of fish. On the central coast, samples from three large basins and one small basin (Siletz, Yaquina, and Alsea rivers, and Beaver Creek) were compared in an attempt to see if the small system (Beaver Creek) had a particular affinity to one of its larger neighbors. Within the Umpqua River, samples were compared from Calapooya Creek, Elk Creek, Smith River, South Fork Umpqua River, and Mainstem Umpqua River. The objective was to look for population structure within this large river basin. The third group of scales was sampled from fish returning to four coastal lakes: Devils Lake, Siltcoos, Tahkenitch, and Tenmile. The lake habitats are distinct from the rivers, and coho from these lakes are thought to be distinct from the coastal river runs.

A phylogenetic tree based on these data (Fig. 8) showed some obvious geographic structure, although the internal branches connecting the geographic groups were relatively short compared to the terminal branches. The samples from the lakes formed a coherent group, as did the samples from the Umpqua Basin. There was some suggestion of structure within each of
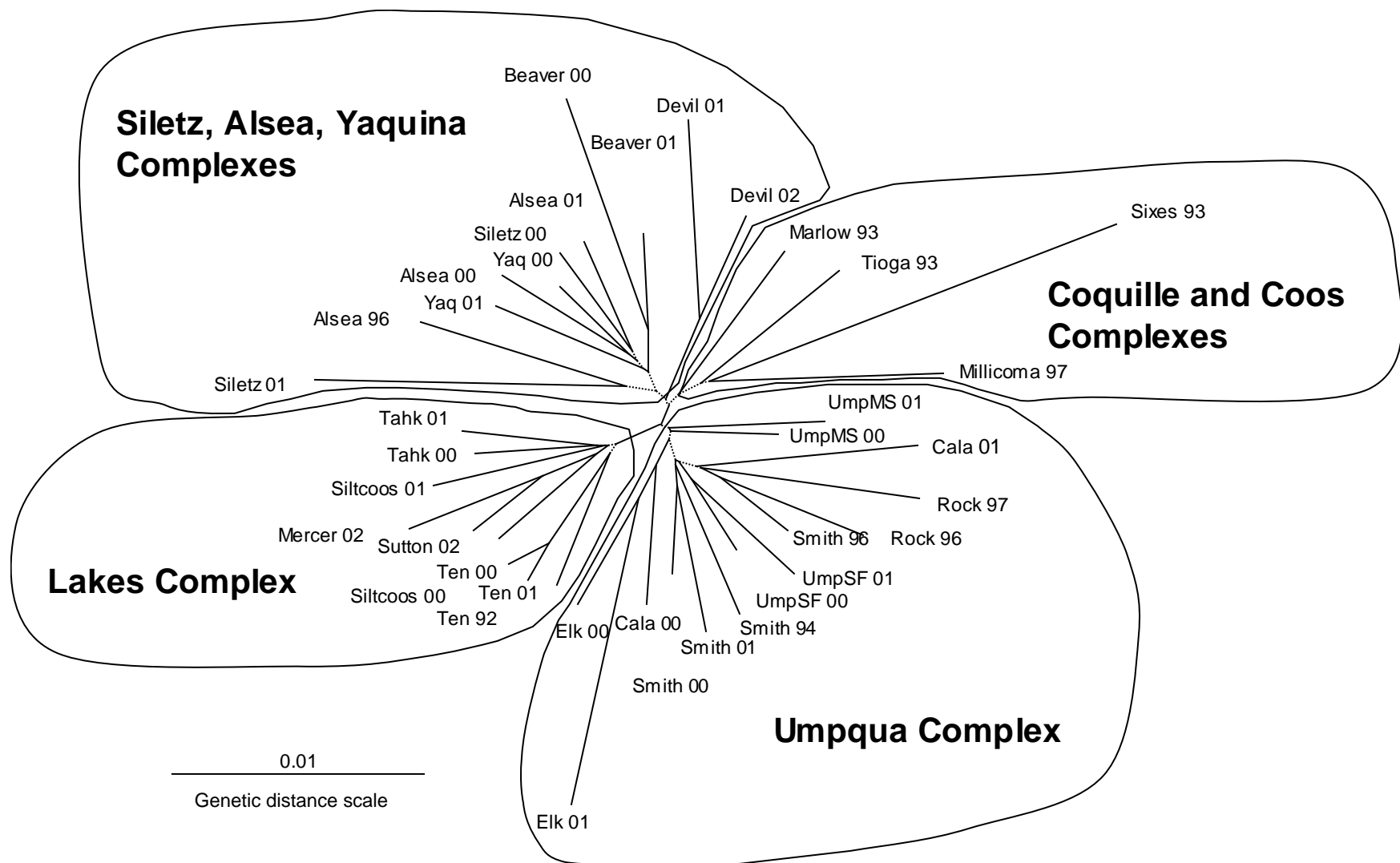
Figure 8.   A maximum likelihood tree of Oregon Coast coho salmon genetic samples. Branches not significantly greater than zero are shown with thin dotted lines. Clusters are outlined by heavy curved line. Analysis by M. Ford based on data from Ford et al. (2004).

these groups. The Siletz, Yaquina, and Alsea rivers, and Beaver Creek also grouped together. There was no population structure identified within this group, although the authors stressed that this was not a strong conclusion. More generally, there is no strong evidence whether or not there are independent populations within these groups. Despite sample size limitations, this study was able to use modern genetic techniques to show a finer scale of population structure than had been demonstrated in earlier studies. In particular, this study supports Siltcoos, Tahkenitch, and Tenmile lakes as at least one independent group. Devils Lake clustered with mid-coast rivers rather than the other lakes. The study also supports dividing the modern populations within the Umpqua Basin into more than one population. There was no clear discrimination among the mid-coast basins. This may be due to recent hatchery practices and stock transfers blurring the boundaries between historical populations.

Homing fidelity

The rate of migration between basins is an important component of our population model. Uremovich (1977) found that, over the seven-year period of 1970-1976, 6.5% of the Chinook carcasses in the Sixes River came from the Elk River hatchery, about 5 km to the north. However, he had no data to indicate the proportion of Elk River fish that were straying. Shapovalov and Taft (1954) found that an average of about 20% of coho spawners in two neighboring streams on the California Coast were migrants from the other stream. These two streams, Waddell and Scott creeks, are small systems with ocean entry points about 8.5 km apart. They saw a pattern in migration rates that suggested variability between years in response to abundance. Such variability certainly occurs on the Oregon Coast, but we have no way at the present time to identify this variability or incorporate it in our isolation models.

We examined freshwater CWT recoveries on the Oregon Coast to test assumptions about patterns of migration between basins. For the period of 1990-2003, 52 tagged coho from 17 Columbia River hatcheries were recovered in freshwater areas of coastal basins. Of the 52 tagged fish, 32 were recovered in 2001, including 4 fish from 3 Oregon hatcheries and 28 fish from 9 Washington hatcheries. Twenty-three of these fish were found in basins from the Umpqua to the Rogue. Surprisingly, 6 of the 52 fish were Cowlitz stock, which is typically considered a north-migrating stock. These data would suggest that migration of Columbia River fish in 2001 was episodic and irregular. Because most of the migrants were found in the largest systems on the coast, it may be that fish originating from large systems prefer other large systems.

Migration patterns between hatcheries on the Oregon Coast may be more relevant to the historical behavior of natural fish. For the period of 1990-2003, there were 71 CWTs from 4 Oregon coastal hatcheries recovered outside the basin of hatchery origin. This represents 0.5% of the CWTs recovered. The actual migration rate is almost certainly higher because CWTs are much more likely to be recovered at the hatchery than on the spawning ground or from freshwater fisheries. In any case, modeling with a 0.5% vs. 5% rate would have no effect on our isolation results. More importantly, the pattern of recoveries showed that most fish were recovered from neighboring basins, falling off rapidly with increasing distance. This supports the negative exponential migration distribution assumed in our isolation model.

Summary of biological characteristics

In conclusion, data for comparison of life-history traits of coho salmon populations on the Oregon Coast are not usually collected at the broad geographic scale that would be useful for distinguishing populations. The data that are available show high variability in run timing, smolt outmigration and spawner returns, jacking rate, and homing fidelity that are largely attributable to environmental variation. Genetic data indicate modern population differences on the scale of regions and, to a lesser extent, individual basins. Lake populations appear different from river populations and the large Umpqua Basin shows genetic differentiation within the basin. However, due to the significant anthropogenic impacts to the landscape, none of these biological characteristics were able to shed light on population structure in historical Oregon Coast coho salmon populations.

Ecological Characteristics

Hydrology

North of Cape Blanco, Oregon, all coastal Oregon rivers, with the exception of the Umpqua River, drain only the west side of the Coast Range. The Oregon Coast Range is relatively low, with peaks at 500-1,000 m (1640-3280 ft) high. Interior portions of the Umpqua Basin, however, drain the east slope Coast Range and the west side of the Cascade Range, which has peaks from 1,000 to 2,000 m (3280-6560 ft) high.

Streamflows in this region follow a similar pattern, with seasonal highs typically experienced in December or January (Fig. 9). Mean annual flows are relatively similar for the basins draining the west slope of the Coast Range. Where they have been measured, these flows have ranged from 0.027 to 0.080 cms per sq. km (Fig. 10). Mean annual flows for the interior drainages within the Umpqua basin have ranged from 0.009 to 0.042 cms per sq. km. Lowest flows generally occur in summer and fall and are a small percentage of the peak flows. Expressed as a percentage of mean flow during the month of greatest runoff, low flows during the month of least runoff range between 1.0% and 5.1% (Fig. 11). The exception to this is the North Umpqua River. The difference in this basin is related to the strong influence of high Cascades geology and hydrology. Duration of high flows range from 4 to 6 months in basins proximal to the coast. In the interior drainages of the Umpqua Basin, high flows can persist for as long as 7 months in unregulated systems (Fig. 12).

Air and stream temperatures

There are few clear broad-scale differences in air or stream temperatures from north to south within coastal areas occupied by the historical Oregon Coast Coho Salmon ESU. Minimum average winter air temperatures are typically around 4ºC (39ºF), whereas minimum average stream temperatures have a range of 4-8ºC (39-46ºF). Maximum average air temperatures are typically around 21ºC (70ºF) and maximum average stream temperatures at selected sites in coastal basins have been observed to range from 15ºC to 21ºC (59-70ºF).
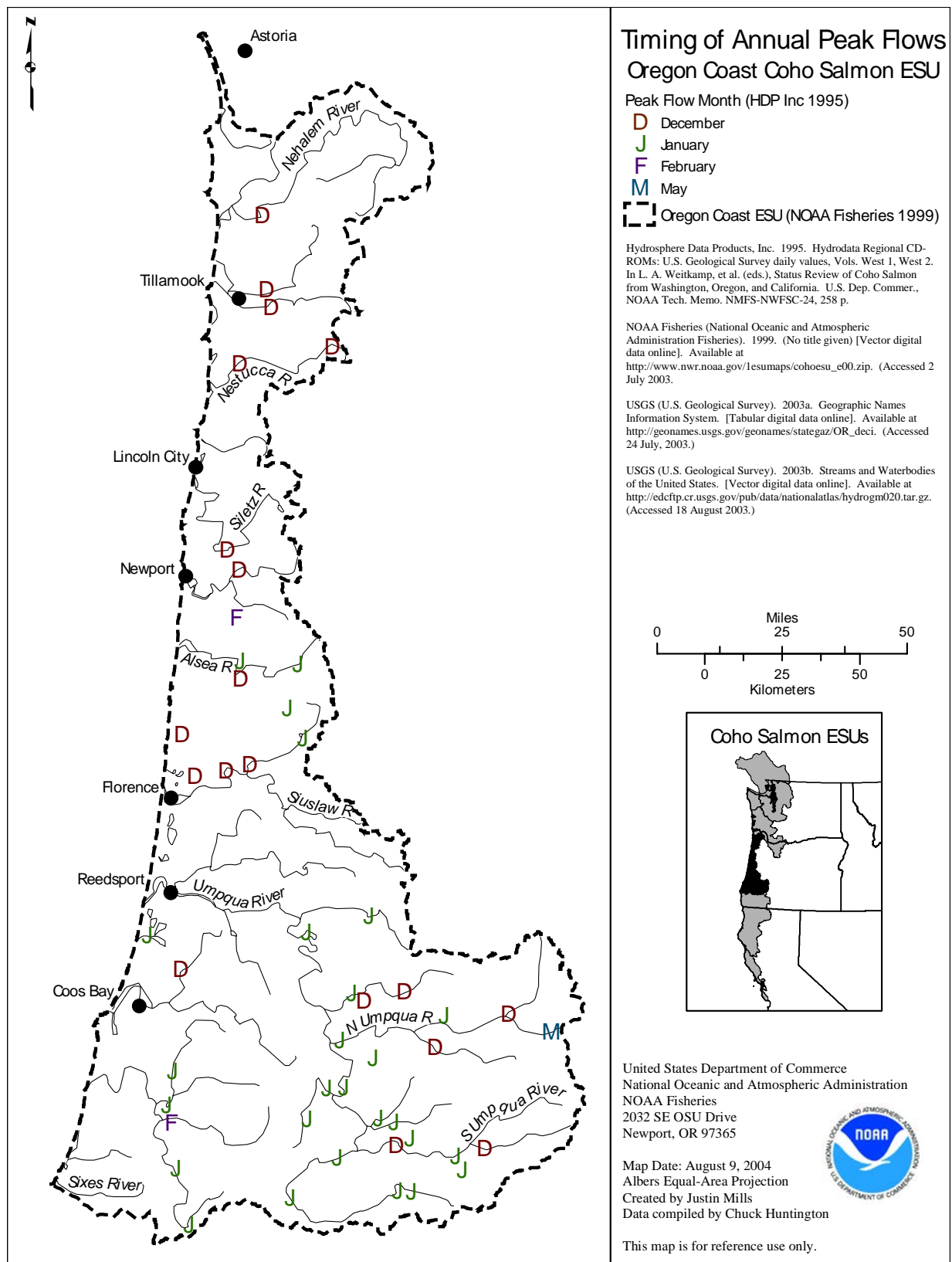
Figure 9.   Timing of annual peak flows in rivers of the Oregon Coast Coho Salmon ESU.
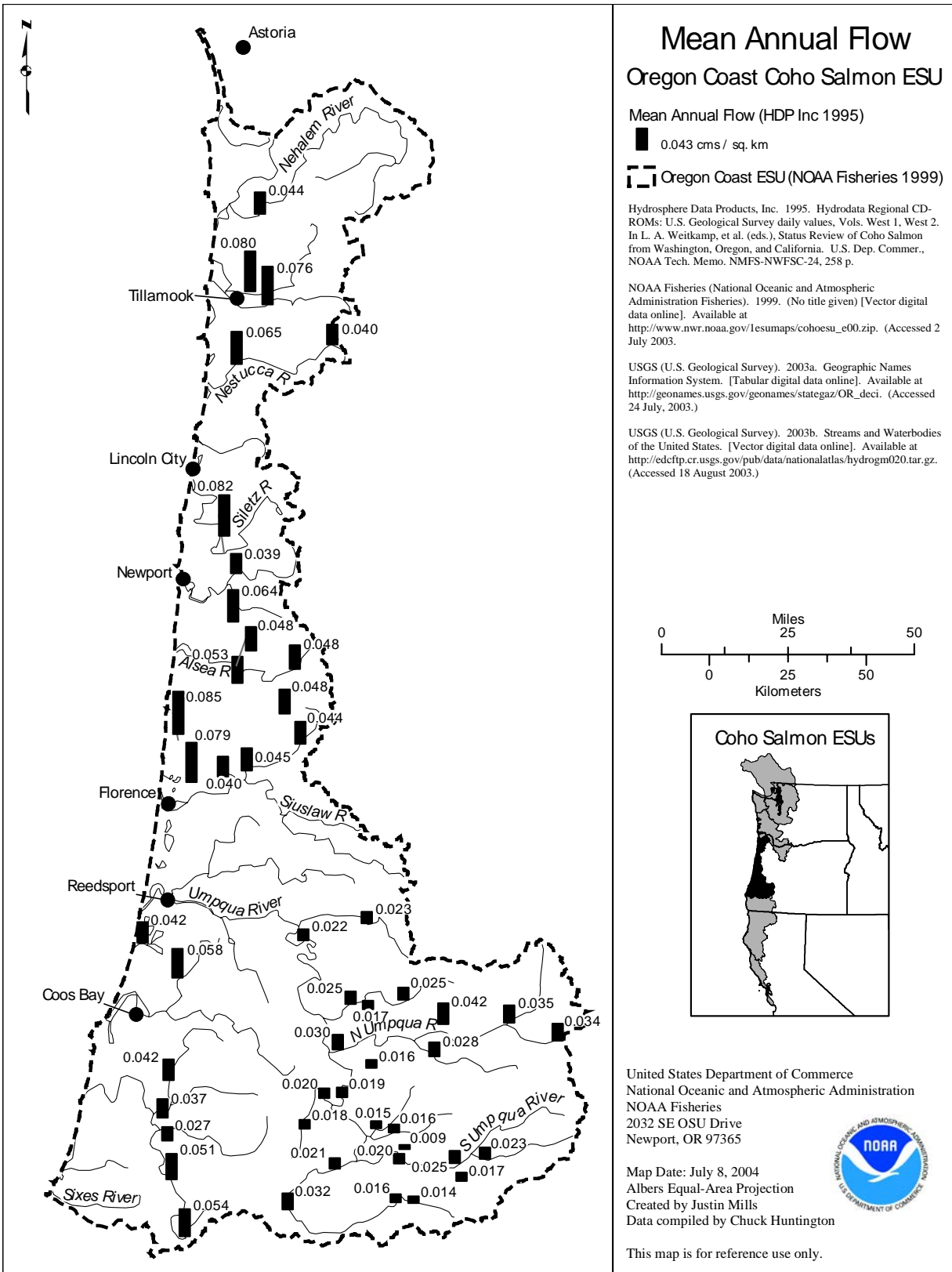
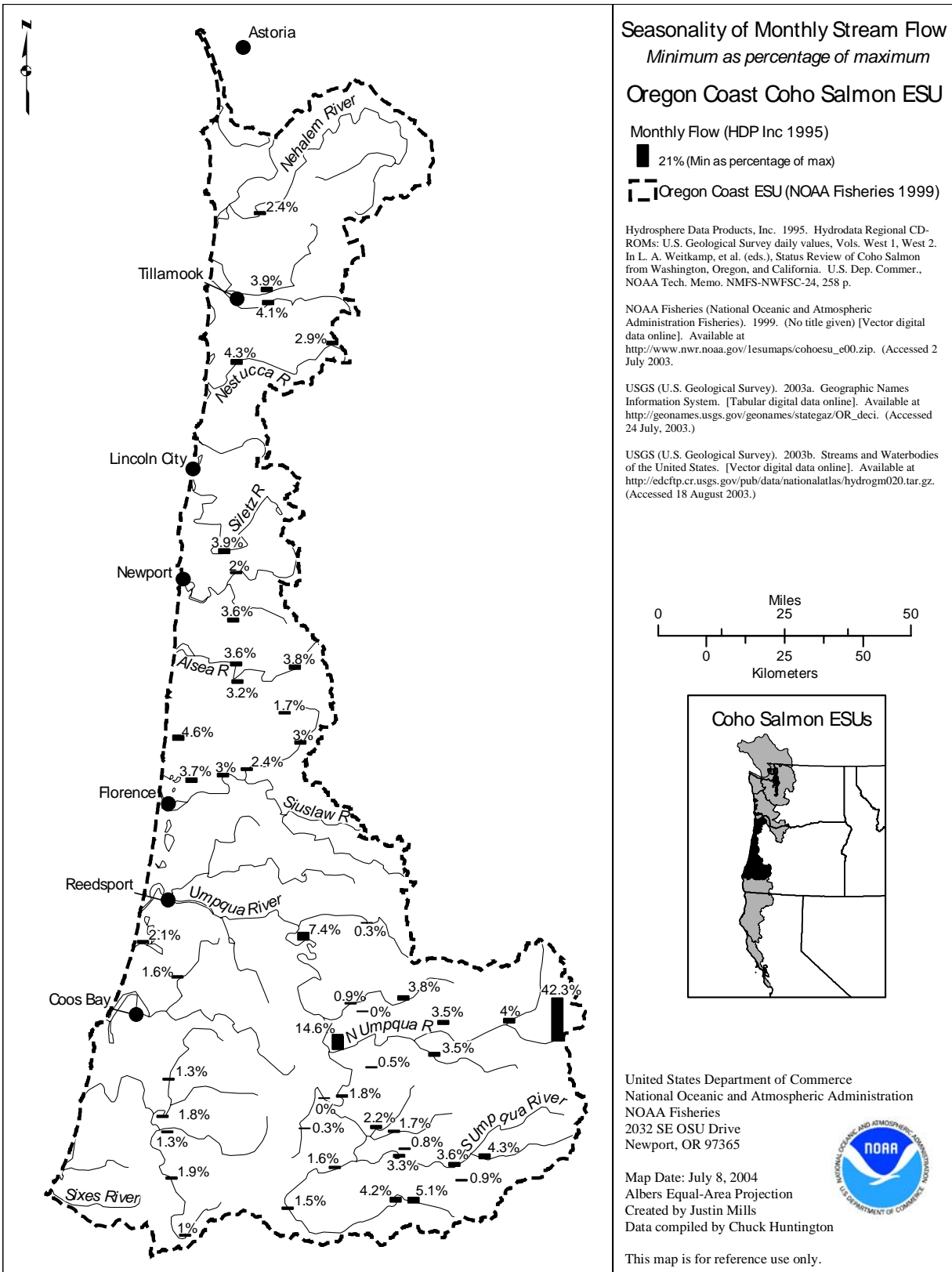Figure 10.   Mean annual flow in rivers of the Oregon Coast Coho Salmon ESU.

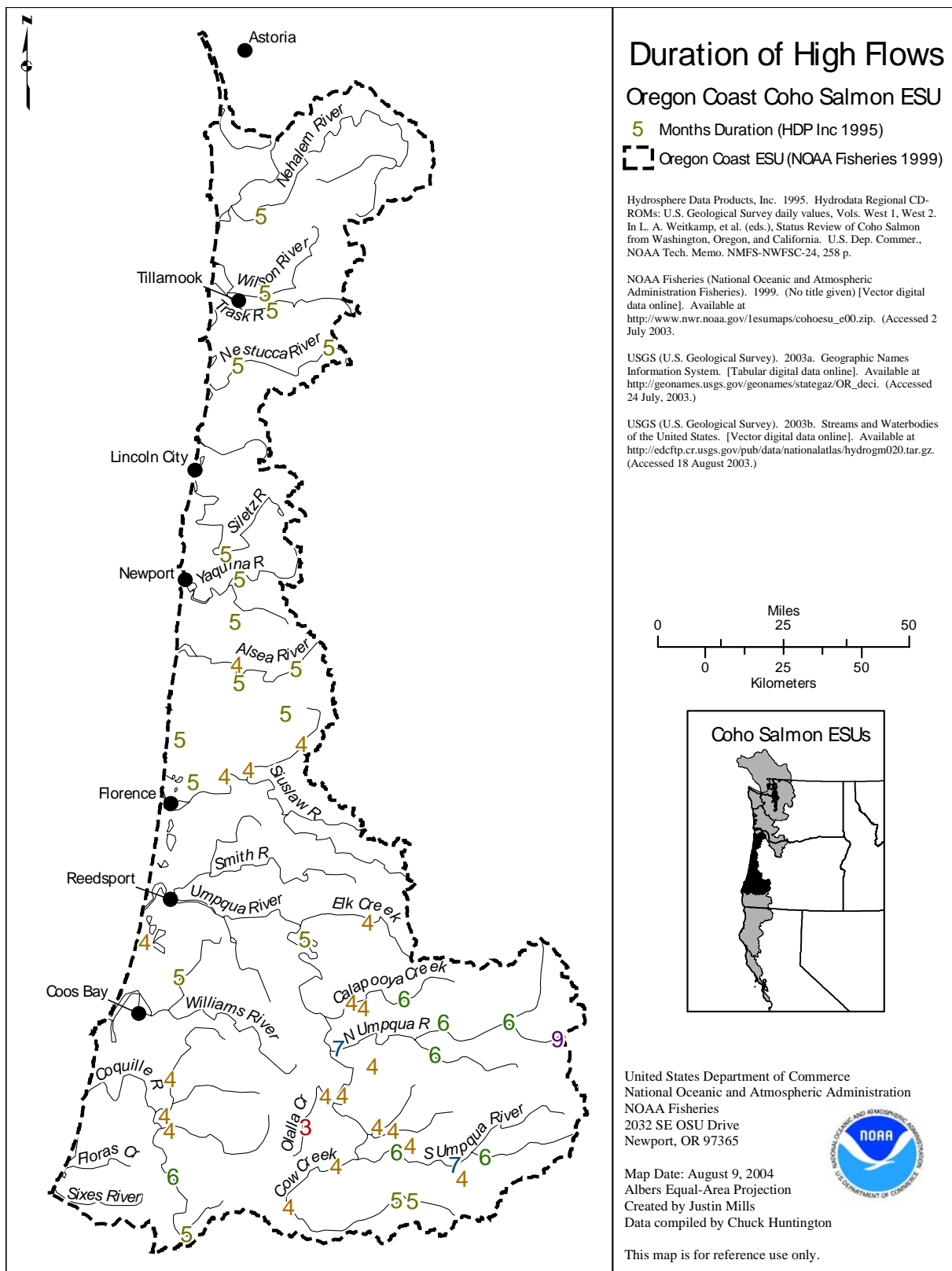Figure 11.   Seasonality of monthly stream flow in rivers of the Oregon Coast Coho Salmon ESU.

Figure 12. Duration of high flows in the Oregon Coast Coho Salmon ESU. The number of months of duration of peak flow is shown at gauging stations.
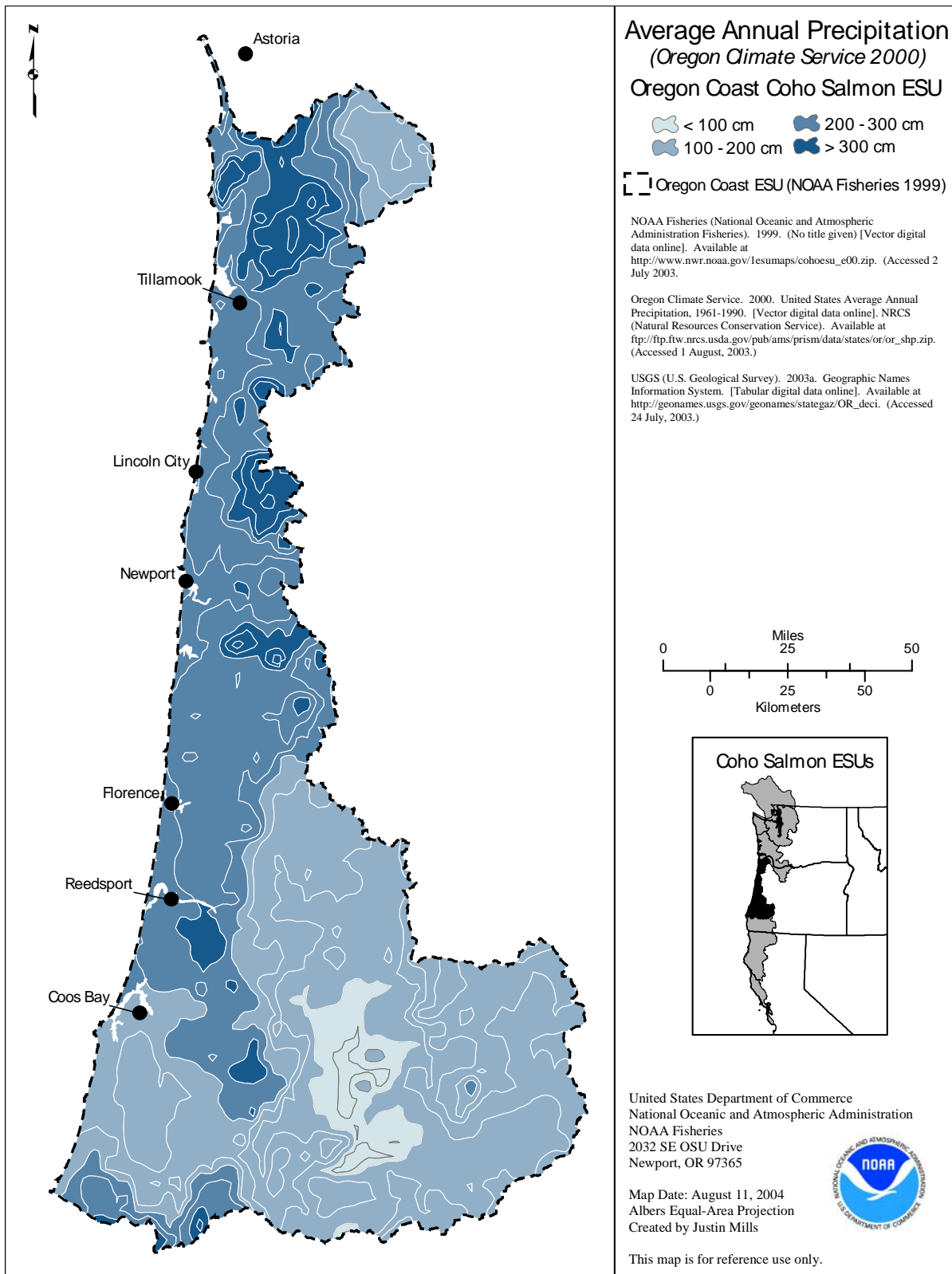
Figure 13.   Average annual precipitation in watersheds of the Oregon Coast Coho Salmon ESU.

Higher maximum stream and air temperatures have been observed in the South Umpqua River, which is an interior basin.

Precipitation

The Oregon Coast receives high rainfall (120–305 cm [47-120 in.] per year) compared to areas east of the Coast Range (60-120 cm [24-47 in.] per year). Generally, however, it receives less rainfall than the Olympic Peninsula, Washington farther north (>240 cm [95 in.] per year). The exceptions to this are in the Nehalem Basin, the upper areas of the five rivers of the Tillamook Basin, and the upper Salmon and Siletz basins (Fig. 13). Much of the Umpqua Basin receives considerably less rainfall than the areas proximal to the coast, with precipitation averages between 102 cm (40 in.) and 152 cm (60 in.). Because of the relatively low elevation, snowfall in the Coast Range is low, averaging 30-60 cm (12-24 in.) annually, while the higher Cascade Range receives from 250 cm (98 in.) to 760 cm (300 in.) annually. This is important for the Umpqua Basin, as the North and South Umpqua Rivers drain a portion of the west slope of the Cascade Range (Oregon Climate Service 2000).

Vegetation

Dominant vegetation types are a valuable indicator of relative precipitation, temperature, soil type, solar radiation, and altitude because of the specific requirements of different forest communities. Consequently, changes of vegetation types can indicate changes in the physical environment, which may affect the freshwater habitat of salmon. (A more detailed discussion of vegetation has been compiled in Appendix I.) Potential vegetation is similar in most of the basins of the Oregon Coast Coho Salmon ESU with the exception of the Siuslaw and Umpqua rivers, which extend into the interior away from marine influence (Fig. 14).

Ecoregion

Ecoregions, as shown in Figures 15 and 16, are representations of the integrations of vegetation, geology, soils, precipitation, and evaporation potential (ONHP 2001). Level 3 ecoregions of the Oregon Coast Coho Salmon ESU from south of the Columbia River to Cape Blanco show large-scale geologic provinces. Level 4 ecoregions show a finer scale of differences, reflecting areas such as coastal lowlands and volcanics, which often indicate differing potential for development of good coho habitat. Descriptions of each type of level 3 and 4 Ecoregion are found in Appendix II.

The ecological information shows a relative uniformity of conditions throughout the Oregon Coast Coho Salmon ESU. This is not surprising, given the dominant effect of the ocean on coastal climate. Differences relate to the effects of topography on rainfall and of geology on vegetation and slope stability. Inland areas of the Umpqua Basin are drier, with more extreme temperatures than the coastal areas. Ecoregions integrate a variety of biotic and abiotic factors to show patterns of habitat variation that may be important to coho salmon.
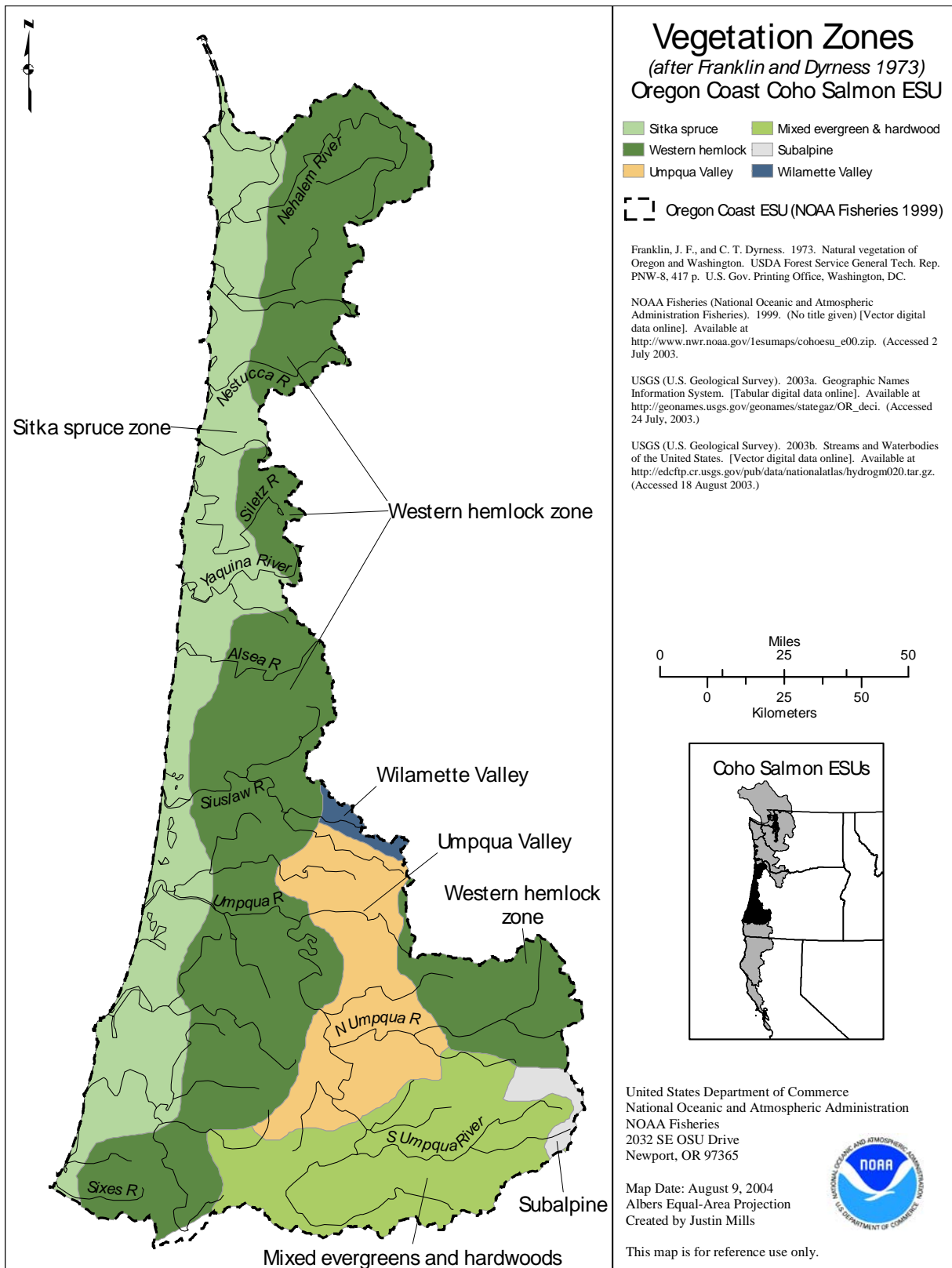
Vegetation Zones
(after Franklin and Dyrness 1973)
Oregon Coast Coho Salmon ESU

Sitka spruce   Mixed evergreen & hardwood
Western hemlock   Subalpine
Umpqua Valley   Wilamette Valley

Oregon Coast ESU (NOAA Fisheries 1999)

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Tech. Rep. PNW-8, 417 p. U.S. Gov. Printing Office, Washington, DC.

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. (No title given) [Vector digital data online]. Available at http://www.nwr.noaa.gov/1esumaps/cohoesu_e00.zip. (Accessed 2 July 2003.

USGS (U.S. Geological Survey). 2003a. Geographic Names Information System. [Tabular digital data online]. Available at http://geonames.usgs.gov/geonames/stategaz/OR_deci. (Accessed 24 July, 2003.)

USGS (U.S. Geological Survey). 2003b. Streams and Waterbodies of the United States. [Vector digital data online]. Available at http://edcftp.cr.usgs.gov/pub/data/nationalatlas/hydrogm020.tar.gz. (Accessed 18 August 2003.)

Coho Salmon ESUs

United States Department of Commerce
National Oceanic and Atmospheric Administration
NOAA Fisheries
2032 SE OSU Drive
Newport, OR 97365

Map Date: August 9, 2004
Albers Equal-Area Projection
Created by Justin Mills

This map is for reference use only.

Figure 14.   Vegetation zones in the watersheds of the Oregon Coast Coho Salmon ESU.
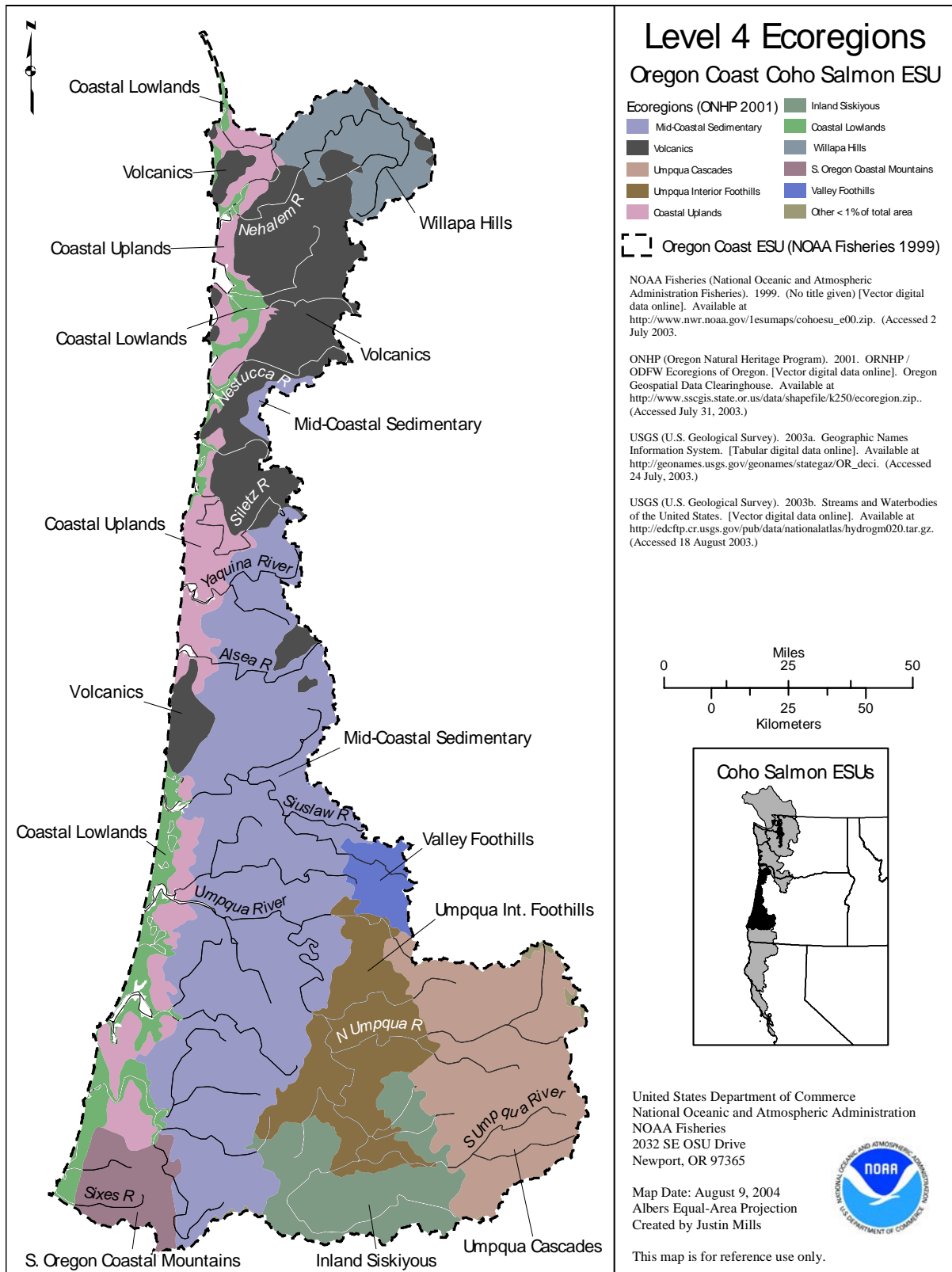
Level 3 Ecoregions

Oregon Coast Coho Salmon ESU

Ecoregions (ONHP 2001)

Coast Range
Klamath Mountains
Cascades
Willamette Valley
Oregon Coast ESU (NOAA Fisheries 1999)

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. (No title given) [Vector digital data online]. Available at http://www.nwr.noaa.gov/1esumaps/cohoesu_e00.zip. (Accessed 2 July 2003.

ONHP (Oregon Natural Heritage Program). 2001. ORNHP / ODFW Ecoregions of Oregon. [Vector digital data online]. Oregon Geospatial Data Clearinghouse. Available at http://www.sscgis.state.or.us/data/shapefile/k250/ecoregion.zip.. (Accessed July 31, 2003.)

USGS (U.S. Geological Survey). 2003a. Geographic Names Information System. [Tabular digital data online]. Available at http://geonames.usgs.gov/geonames/stategaz/OR_deci. (Accessed 24 July, 2003.)

USGS (U.S. Geological Survey). 2003b. Streams and Waterbodies of the United States. [Vector digital data online]. Available at http://edcftp.cr.usgs.gov/pub/data/nationalatlas/hydrogm020.tar.gz. (Accessed 18 August 2003.)

Astoria

Tillamook

Nehalem River

Nestucca R

Lincoln City

Siletz R

Newport

Yaquina River

Coast Range

Alsea R

Willamette Valley

Florence

Siuslaw R

Klamath Mountains

Reedsport

Umpqua River

Cascades

Coos Bay

N Umpqua R

S Umpqua River

Sixes River

Miles
0   25   50

0   25   50
Kilometers

Coho Salmon ESUs

United States Department of Commerce
National Oceanic and Atmospheric Administration
NOAA Fisheries
2032 SE OSU Drive
Newport, OR 97365

Map Date: August 9, 2004
Albers Equal-Area Projection
Created by Justin Mills

This map is for reference use only.

Figure 15.   Level 3 Ecoregions of the Oregon Coast Coho Salmon ESU.

Level 4 Ecoregions
Oregon Coast Coho Salmon ESU

Ecoregions (ONHP 2001)

- Mid-Coastal Sedimentary
- Volcanics
- Umpqua Cascades
- Umpqua Interior Foothills
- Coastal Uplands
- Inland Siskiyous
- Coastal Lowlands
- Willapa Hills
- S. Oregon Coastal Mountains
- Valley Foothills
- Other < 1% of total area

Oregon Coast ESU (NOAA Fisheries 1999)

NOAA Fisheries (National Oceanic and Atmospheric Administration Fisheries). 1999. (No title given) [Vector digital data online]. Available at http://www.nwr.noaa.gov/1esumaps/cohoesu_e00.zip. (Accessed 2 July 2003.

ONHP (Oregon Natural Heritage Program). 2001. ORNHP / ODFW Ecoregions of Oregon. [Vector digital data online]. Oregon Geospatial Data Clearinghouse. Available at http://www.sscgis.state.or.us/data/shapefile/k250/ecoregion.zip.. (Accessed July 31, 2003.)

USGS (U.S. Geological Survey). 2003a. Geographic Names Information System. [Tabular digital data online]. Available at http://geonames.usgs.gov/geonames/stategaz/OR_deci. (Accessed 24 July, 2003.)

USGS (U.S. Geological Survey). 2003b. Streams and Waterbodies of the United States. [Vector digital data online]. Available at http://edcftp.cr.usgs.gov/pub/data/nationalatlas/hydrogm020.tar.gz. (Accessed 18 August 2003.)

Miles
0   25   50

0   25   50
Kilometers

Coho Salmon ESUs

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Map labels: Coastal Lowlands, Volcanics, Coastal Uplands, Coastal Lowlands, Willapa Hills, Volcanics, Mid-Coastal Sedimentary, Coastal Uplands, Volcanics, Mid-Coastal Sedimentary, Coastal Lowlands, Valley Foothills, Umpqua Int. Foothills, Umpqua Cascades, Inland Siskiyous, S. Oregon Coastal Mountains

Rivers: Nehalem R, Nestucca R, Siletz R, Yaquina River, Alsea R, Siuslaw R, Umpqua River, N Umpqua R, S Umpqua River, Sixes R

Figure 16.   Level 4 Ecoregions of the Oregon Coast Coho Salmon ESU.

Summary of potential isolating ecological characteristics

We reviewed a wide range of factors of potential use in distinguishing among populations of coho salmon on the Oregon Coast. Most of the data indicated differences on a broad scale, but there were few data sets useful at the finer scale of individual basins. The most recent genetic analysis indicated that modern populations are probably structured at a smaller scale than broad regions (north coast – south coast). Geographic isolation is potentially useful for defining the degree of interactions among populations, and ecoregions may define habitat divisions significant to life history adaptations that could potentially become isolating factors in population structure. These more enduring ecological characteristics (which include geological history, vegetation, and climate) appear to be more informative when considering the historical population structure of Oregon Coast coho salmon. These were especially useful when considering the Umpqua Basin.

Methods for Population Identification and Classification

We identified two steps for defining populations and their structure: (1) identifying population units, and (2) classifying the units into categories. Identification delineates populations and defines where they occur. Classification categorizes those populations into groups. Based on our conceptual model, we defined three groups: Functionally Independent populations, Potentially Independent populations, or Dependent populations. Both steps are based on simple rules.

Population Identification Method

We used two rules for identifying populations. The first identifies all main basins that encompass the range of one or more populations:

Rule 1: No population will span saltwater; in other words, populations are divided at saltwater entry such that each direct ocean tributary wholly encompasses the range of any populations that spawn within the freshwater basin. For purposes of this rule, estuaries are considered part of the freshwater system, so that multiple streams entering a single bay may contain a single population.

This rule is based on two postulates regarding salmon populations. First, population structure is largely determined by the structure of freshwater spawning and rearing habitats and the migration pathways connecting these habitats. Second, saltwater entry/exit is a major break point in migration pathways, so that migration among habitats within a basin is more likely than migration through saltwater among basins. Coho salmon spawn and rear in freshwater, which allows periods of migration for juveniles before saltwater entry and for adults during spawning migrations.

Applying Rule 1, we identified 66 direct ocean exit basins with coho salmon habitat within the range of the Oregon Coast Coho Salmon ESU (Table 1). These basins range in size from Rover Creek (60 ha [148 ac.]) to the Umpqua River Basin (1.2 million ha [3 million ac.]).

The second rule describes when a basin contains more than one persistent population:

Rule 2: To be considered separate populations, two breeding groups within a basin must be sufficiently isolated to be considered Functionally or Potentially Independent.

Evidence for isolation may include major ecological differences among subbasins, large spatial separation of spawning and rearing habitats, or noteworthy life history or genetic differences. Under Rule 2, we considered subdividing several of the larger basins into multiple populations. These are discussed from north-to-south below.

Population Identification Results

Nehalem River

We considered defining two populations within the basin divided just below the confluence of the mainstem and Humbug Creek. In favor of this split is the geological distinctness of the upper basin, which is largely in the Willapa Hills Ecoregion (Fig. 16). However, there was no apparent isolating mechanism to limit migrations between spawning areas in the upper and lower basins, and the upper basin is ecologically similar to the North Fork, which would have been included in the lower population.

Tillamook Bay

Tillamook Bay drains several moderate-sized rivers—Miami, Kilchis, Wilson, Trask, and Tillamook—each of which could have supported an independent coho population, and thus we considered subdividing the basin into multiple populations. However, we ultimately concluded that historically there probably were not separate populations in this basin. Considerations leading to this conclusion included: (1) habitat is ecologically similar across the rivers, (2) most historical production was in lowland areas, where tributaries are close together and likely merged during floods (Coulton, Williams, and Benner 1996), and (3) most coho habitat is in the Tillamook, Trask, and Wilson Rivers, which are all close together. The Miami River is somewhat separated geographically from the other main tributaries, but was probably not large enough to support a Functionally or Potentially Independent population without input from its neighbors. At present, coho habitat is widely dispersed in the upper reaches of the tributaries; however, this appears to be largely a result of loss of higher quality lowland habitats rather than the natural structure of the population.

Nestucca Bay

Kostow (1995) identified two tributary populations (Nestucca and Little Nestucca Rivers). We found no significant ecological differences or isolating mechanisms between the two tributaries to justify subdividing the population.

Siletz Bay

Kostow (1995) identified three populations entering Siletz Bay. We found no significant ecological differences or isolating mechanisms among the tributaries to justify subdividing the population.

Siuslaw River

Two populations (Siuslaw and North Fork Siuslaw) were identified by Kostow (1995). We considered separating the North Fork from the main river, but found no significant ecological differences, and noted likely historical lowland habitat connections between the two rivers.

Umpqua River

This is a large basin (Table 1) draining a diverse region (Fig. 3). We considered several possible population scenarios with between one and five populations in the basin. The single population scenario was eliminated early, because of the size of the basin, its ecological diversity as indicated by multiple level-three and level-four ecoregions (Figs. 15 and 16), and the apparent genetic diversity within the basin (Fig. 8) (Ford et al. 2004). The finest-scale divisions we considered included independent populations in the North Umpqua River, South Umpqua River, mainstem Umpqua River, lower Umpqua Basin (lower mainstem and bay tributaries), and Smith River. The Smith River, a large tributary entering the Umpqua River below tidewater, was eliminated from consideration as a historically independent population because until 1930 most of the habitat in the basin was inaccessible due to an impassable falls low in the basin. In addition, the lower reaches of the Smith River are geographically close and ecologically similar to other lower basin streams.

Given these considerations, we reduced the likely scenarios to two: (1) dividing the basin geographically into three populations based on 4th-field Hydrologic Units (HUC) (Smith River and mainstem to the forks, North Fork, and South Fork), and (2) dividing the basin into two populations based on dominant level-3 ecoregions (Fig. 15) within subbasins. The HUC-based approach is appealing for simplicity, and recognizes that major tributary branches within basins are possible isolating points for migrating adults. The ecoregion approach focuses more on potential isolation via local adaptation to geology, hydrography, and vegetation differences among regions. The Umpqua Basin spans four level-3 ecoregions: Coast Range, Klamath Mountains, Willamette Valley, and Cascades. However, the latter two historically had little coho salmon habitat (Figs. 4 and 15). The two dominant ecoregions are the Coast Range, which spans the lower tributaries and mainstem, except for Elk and Calapooya Creeks, and the Klamath Mountains, which spans upper Elk Creek, Calapooya Creek, and the lower portions of the North and South Umpqua Rivers.

There are large uncertainties inherent in reconstructing historical population patterns, and there is no clear support favoring one of these scenarios over the other. Recent genetic analysis (Fig. 8) (Ford et al. 2004) supports some division within the basin, but patterns of genetic variation are ambiguous and we do not know to what extent they reflect recent management rather than historical population structure. Pending further evidence, we provisionally identified

two historical populations based on ecoregion differences within the Umpqua River Basin: Lower Umpqua River and Upper Umpqua River (Fig. 15), with the division in the mainstem immediately below the confluence of Elk Creek. The Lower Umpqua River population occupies the Coast Range Ecoregion, while the Upper Umpqua River population inhabits primarily the Klamath Mountains Ecoregion, with some habitat in the Cascades and Coast Range ecoregions. As we develop further analyses regarding viability criteria and recovery actions, we will consider the consequences of different ways of subdividing this basin.

Coos Bay

We considered splitting the South Fork and Millicoma River as separate populations, following the lead of Kostow (1995). However, this was rejected because of lowland habitat connections in the lower basin where much historical production likely occurred, similar to the situation in Tillamook and Siuslaw Bays.

Population Classification

We classified historical populations into the three population categories: Functionally Independent, Potentially Independent, and Dependent, based on relative persistence and degree of isolation. Because no direct measure of persistence was available, we used historical potential population size as a proxy. We reconstructed historical population potential from a landscape-based model (App. III, Burnett et al. 2003). We then used an isolation model based on the distances between the ocean entry points of basins (Bjorkstedt 2004). These models are described in the following sections.

Population Classification Methods

Historical population size (persistence)

We used habitat metrics and recent studies of relationships between habitat and juvenile production to estimate historical abundance. Of course, using current habitat metrics to derive an index of historical abundance requires measuring habitat features that are relatively stable over time. Therefore, we used geomorphic measures of stream conditions that can be calculated from current GIS databases (Coastal Landscape Analysis and Modeling Study [CLAMS]) and digital elevation models (DEMs), adjusted for known changes in the landscape (such as construction or removal of migration barriers) (Burnett et al. 2003). To estimate historical abundance, we combined key geomorphic measures (gradient, valley width, and active channel width) from the DEMs with habitat intrinsic potential (an integrated measure of habitat quality described in Burnett et al. 2003 and illustrated in Figs. III-2 through III-5 in App. III), smolt capacity estimates for different types of habitat, and a smolt-to-adult survival rate based on a good marine survival year. We compared these habitat-based estimates with estimates derived from cannery records from the turn of the century to confirm that our estimates were reasonable (Lichatowich 1989). Appendix III presents a detailed description of the methods used to estimate these potential historical population sizes.

Table 6.   Potential historical smolt and adult abundance for 67 putative populations of coho salmon in the Oregon Coast Coho Salmon ESU (App. III).

Population	Potential smolts	Adults @ 10% marine survival	Population	Potential smolts	Adults @ 10% marine survival
Necanicum R.	685,000	68,500	Moore Cr.	1,000	100
Indian Cr.	100	10	Theil Cr.	20,000	2,000
Canyon Cr.	400	40	Beaver Cr.	265,000	27,000
Ecola Cr.	72,000	7,000	Alsea R.	1,628,000	163,000
Red Rock Cr.	100	10	Little Cr.	1,000	100
Austin Cr.	300	30	Big Cr.	34,000	3,000
Asbury Cr.	1,000	100	Vingie Cr.	3,000	300
Arch Cape Cr.	3,000	300	Yachats R.	110,000	11,000
Short Sand Cr.	4,000	400	Gwynn Cr.	1,000	100
Nehalem R.	3,330,000	333,000	Cummins Cr	10,000	1,000
Spring Cr.	5,000	500	Bob Cr.	6,000	600
Watseco Cr.	5,000	500	Tenmile Cr.	28,000	3,000
Tillamook Bay	3,288,000	329,000	Squaw Cr.	100	10
Netarts Bay	15,000	1,500	Rock Cr.	6,000	600
Rover Cr.	2,000	200	Big Cr.	18,000	2,000
Sand Cr.	123,000	12,000	China Cr.	5,000	500
Nestucca R.	1,037,000	104,000	Blowout Cr.	1,000	100
Neskowin Cr.	49,000	5,000	Cape Cr.	15,000	2,000
Salmon R.	168,000	17,000	Berry Cr.	54,000	5,000
Devils Lake	85,500	9,000	Sutton Cr.	84,000	8,000
Siletz R.	1,217,000	122,000	Siuslaw R.	2,674,000	267,000
Schoolhouse Cr.	2,000	200	Siltcoos R.	771,000	77,000
Fogarty Cr.	18,000	2,000	Tahkenitch Cr.	228,000	23,000
Depoe Bay Cr.	7,000	700	Threemile Cr.	22,000	2,000
Rocky Cr.	10,000	1,000	Umpqua (total)	8,199,000	820,000
Johnson Cr.	22,000	2,000	Lwr. Umpqua	1,293,000	129,000
Spencer Cr.	11,000	1,000	Upr. Umpqua	6,906,000	691,000
Wade Cr.	5,000	500	Tenmile Cr.	525,000	53,000
Coal Cr.	4,000	400	Coos Bay	2,058,000	206,000
Moolack Cr.	4,000	400	Coquille R.	4,169,000	417,000
Big Cr.	26,000	3,000	Johnson Cr.	8,000	800
Yaquina R.	1,217,000	122,000	Twomile Cr.	134,000	13,000
Henderson Cr.	1,000	100	Floras Cr.	396,000	34,000
Grant Cr.	400	40	Sixes R.	372,000	37,000
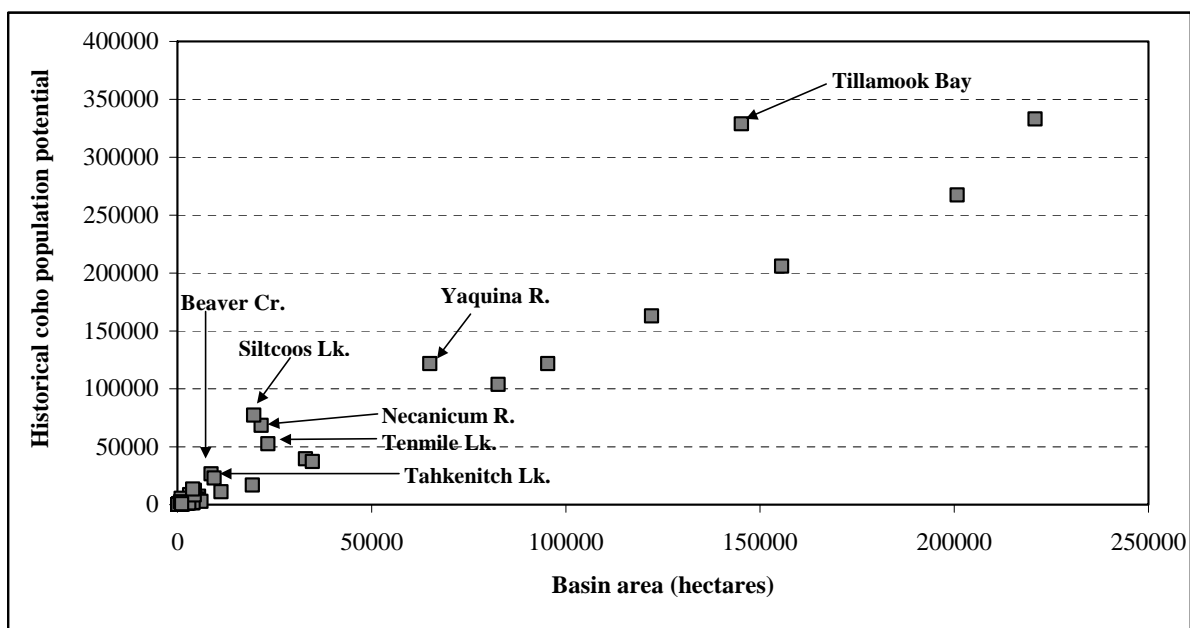
Figure 17. Historical coho population potential versus basin area for Oregon Coast basins (Data sources: Streamnet 2003, App. III).

The advantage of calculating adult abundance from computed GIS data is that estimates can be made for basins where there are no historical fishery data. Table 6 lists the estimated potential historical abundance of coho salmon for the 67 populations in the Oregon Coast Coho Salmon ESU delineated by the process of identification described above. Total adult abundance derived from smolt numbers and a 10% marine survival rate was about 3.3 million adults if all populations peaked in the same year.

Our GIS-based modeling of the historical capacity of Oregon Coast basins to produce coho salmon shows considerable between-basin variation in the ability to produce these fish. Large coastal basins have a greater absolute capacity to produce coho than do smaller basins because they contain a greater abundance of suitable habitat (Fig. 17). However, the potential of Oregon Coast basins to produce coho is influenced by habitat quality as well as quantity. Some basins are inherently more productive for these fish than are others because they have the capacity to form disproportionate quantities of the kinds of complex, low-gradient habitats most favored by coho salmon. These basins, including Tillamook Bay, Yaquina River, Beaver Creek, the lake basins (Siltcoos Lake, Tenmile Lake, Tahkenitch Lake) and others, once produced more coho than would be expected on the basis of their size alone because they contain disproportionately large lowland areas (or lakes) that can provide highly productive rearing environments for juvenile coho.

When compared in terms of their historical capacity to produce coho per unit of basin area, larger basins on the Oregon Coast appear to have been generally more productive than smaller basins because they were more likely to contain relatively extensive lowland areas and complex low-gradient habitats (Fig. 18). Though there were exceptions to this pattern, as

indicated earlier, the lower inherent productivity of the smaller basins tended to make the coho populations within them even smaller than expected on the basis of basin size alone. This made the coho populations within these smaller basins particularly vulnerable to periodic local extinctions unless there was a consistent influx of stray spawners from larger basins. The relatively higher vulnerability of these populations is attributable to demographic risks associated with small population size, to increased sensitivity to fluctuations in marine survival due to lower freshwater productivity, and to the vulnerability of small natal basins to single catastrophic disturbances.

Isolation (proportion of native spawners)

One of the defining properties of salmon is their propensity to undergo a long ocean migration and return with high fidelity to their natal spawning grounds. This is what isolates salmon populations from one another. However, homing is not perfect, and the movement of migrant salmon between populations is also a defining property of salmon populations. The degree of isolation between populations is determined by the proportion of salmon adults that are migrants from another population and the effectiveness of these migrant salmon at placing competetive offspring into the habitat to which they stray. The proportion of migrants into a population also affects the demographic independence of each population. Our rules for classifying a population are based on a calculation of historical abundance and on the proportion of non-migrant or native spawning adults based on distances between populations and the relative sizes of these populations.

We used an isolation model developed by Bjorkstedt (2004) to calculate the relative isolation of each population on the Oregon Coast. Quantitative data on coho salmon dispersal rates are lacking so the model is relatively simple, reducing the number of assumptions at the risk of reducing the descriptive power of the model. Dispersal of migrants among basins separated by saltwater is modeled as a function of distance between the mouths of ocean tributaries. All basins were treated as single units. Thus, the Umpqua Basin, where two populations were delineated, was treated as a single population from the perspective of its neighbors.

In this model, fidelity to native basins (proportion of native spawners) was assumed a constant 95% of potential returning adults. We used our estimates of historical abundance as the number of returning adults for each population. The remaining 5% of the returning population dispersed as migrants along the coast with an exponential decline with distance (Bjorkstedt 2004). After they were dispersed along the coast, they entered the basin nearest to their final location. Distances among watersheds along the Oregon Coast were calculated using the latitude-longitude coordinates for the mouths of each river. The distance between each pair of neighboring river mouths was calculated "as the crow flies." Distances between non-neighboring rivers were calculated as the sum of all intervening neighbor-pair distances. In this way, the curvature of the coast was included in the distance calculations. Tributaries of Tillamook Bay were considered as a single watershed. Two out-of-ESU systems, the Columbia River, to the north, and Elk River, to the south, were included to allow estimation of migrants across the ESU boundaries. Elk River historical abundance was estimated from Intrinsic Potential. Columbia River abundance was based on Chapman (1986).
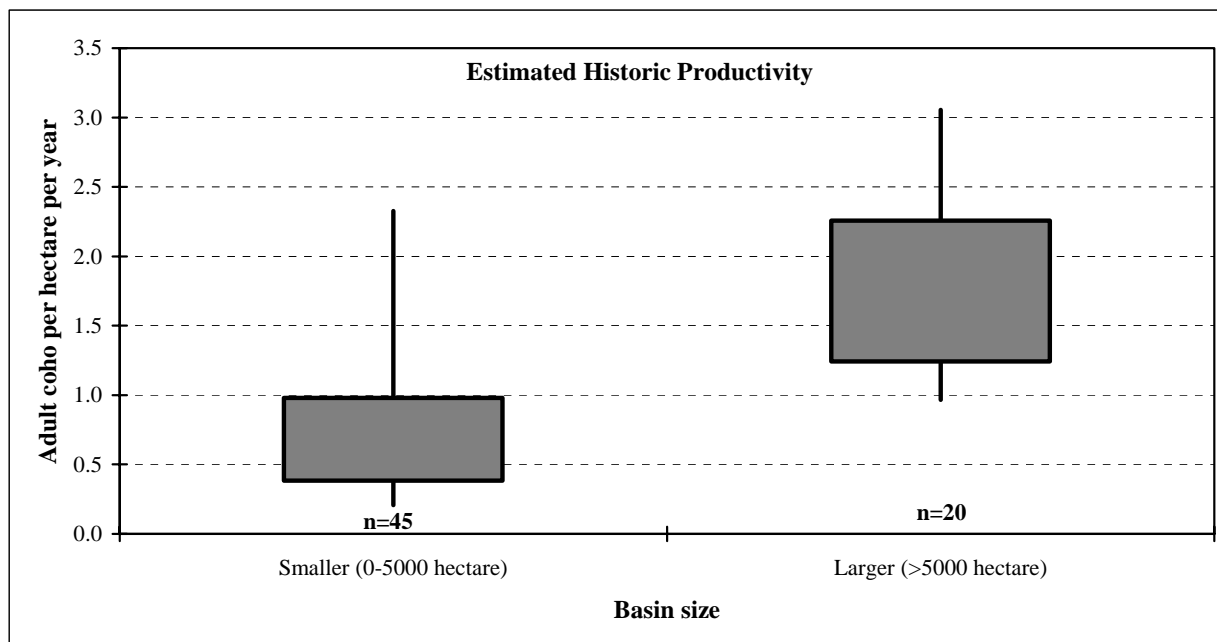
Figure 18.   Box-whisker plots of estimated historical coho productivity (adults per hectare of basin area per year) for Oregon Coast basins smaller and larger than 5000 hectares. Boxes depict the 25th to 75th percentile productivity values for basins of a given size; whiskers extend to the 10th and 90th percentile values (Data source: Streamnet 2003, App. III).

Population Classification Results

The isolation model reports the proportion of spawners in each stream that originated from that stream (proportion of native return). Streams with a higher proportion of native return are more isolated. Figure 19 is an analysis of Relative Independence based on the isolation of each population in the ESU and the historical population size (persistence). It shows a continuum from small, dependent populations to large, independent populations. Defining the relative roles of populations on this continuum required us to create divisions that were, to some extent, artificial and arbitrary. We focused on understanding the axes of isolation and historical population size in terms of the analytical techniques used and the population dynamics. We were concerned with finding criteria for these break points that were realistic and defensible in terms of existing analyses.

Establishing a horizontal line to distinguish the Functionally Independent populations was straightforward because of the model structure. The native return rate used in the model was 95%. Thus, all populations with greater than 95% proportion native return were net donors, and those with fewer than 95% proportion native return were net receivers. The horizontal line at [0.95] in Figure 19 depicts this division.
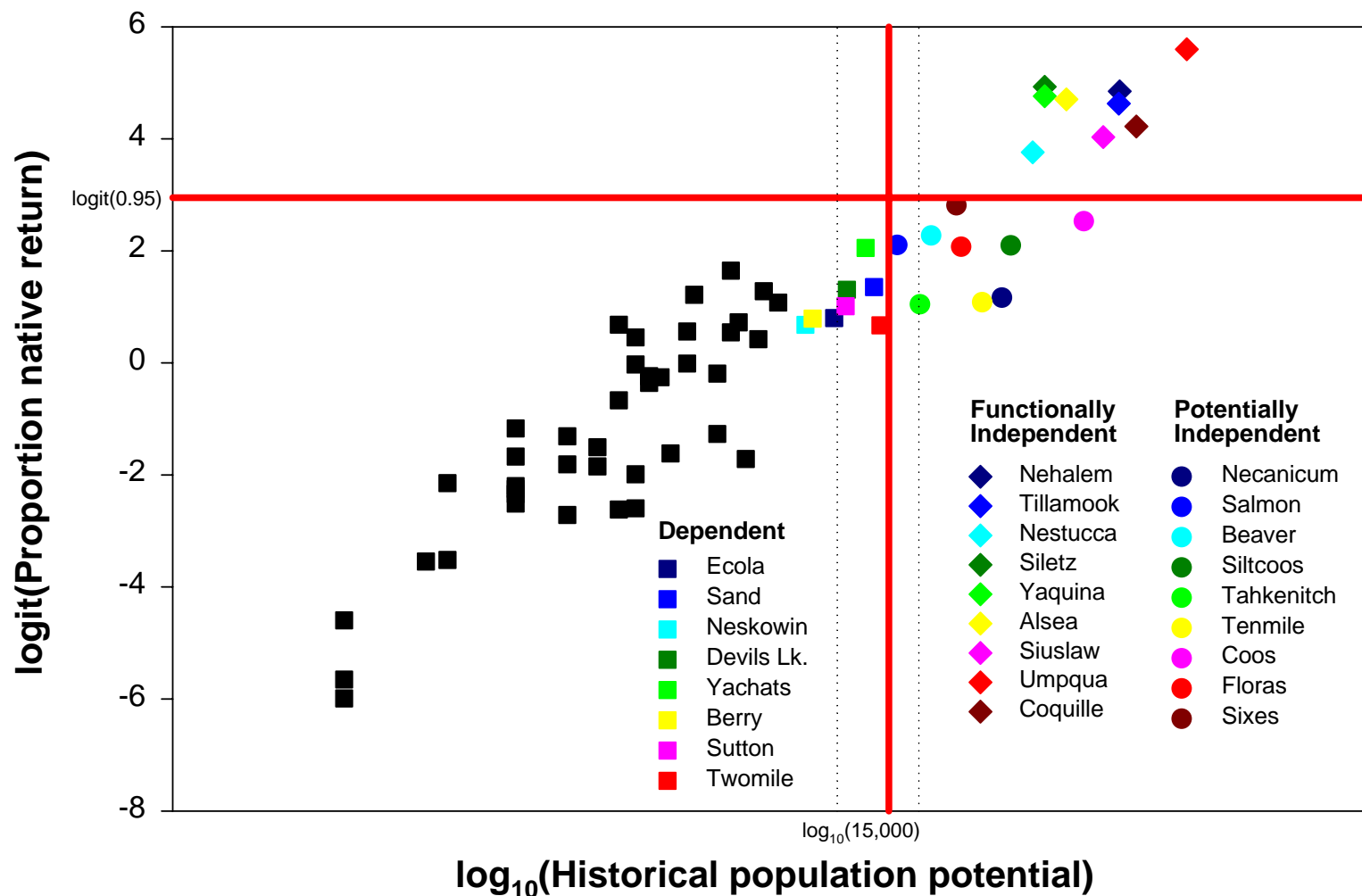
Figure 19. Isolation analysis for Oregon Coast coho salmon using estimates of potential historical coho salmon abundance and a dispersal model in which fidelity is fixed at 95% and dispersers are spread across neighboring watersheds according to an exponential decline with distance (decay parameter = 0.05). This includes the influence of the Columbia and Elk rivers. The solid horizontal line represents the isolation criterion of 95% native spawners. The solid vertical line represents the persistence criterion of 15,000 adult coho at 10% marine survival. The dotted vertical lines represent +/- 50% of 15,000.

Establishing a vertical line to distinguish between persistent and non-persistent populations was more difficult. As population abundance, or their habitat areas (or capacity), gets smaller, the probability of extinction rises. It is, however, harder to quantify that probability than it is to characterize the functional relationship between habitat size and extinction probability. The stochastic life-cycle model (Nickelson and Lawson 1998) produces quantitative extinction probabilities. However, these probabilities are sensitive to many of the model parameters, including patterns of freshwater production, density dependence, straying, and marine survival. As a consequence, we were unwilling to use the absolute extinction probabilities from the model to define the vertical line criterion. We were, however, more comfortable with the qualitative model result; as habitat quantity decreases, extinction probability increases exponentially. We chose as our criterion for persistence the point where the probability of extinction started to increase rapidly (Fig. 20). We considered 32 km (15 miles) of habitat as the break point. The resulting habitat quantity would be expected to produce 15,000 adult spawners at 10% marine survival, so we set the vertical line at 15,000 adult spawners on the historical population potential axis. This does not mean that populations to the left of this point would necessarily go extinct in 100 years without input from other populations. It does mean that the probability of such extinctions is high enough so that on an evolutionary time scale of tens to thousands of years, we expect such extinctions to be a normal part of the populations' dynamics and reflected in the genetic population structure.

We explored the effect of increasing or decreasing this number by 50% (7,500 or 22,500), as represented by the vertical dotted lines in Figure 19. If our estimate is low only one basin, the Salmon River, would be reclassified as Dependent. With a high estimate, five of the larger Dependent populations (Twomile, Sand, Yachats, Devils Lake, and Sutton Lake) would be reclassified as Potentially Independent.

Fifteen thousand adult spawners sounds, at first, like a high threshold for persistence. However, the historical population potential was calculated as a maximum, assuming 10% marine survival. In years with 1% marine survival, as we have experienced recently, these populations would have been below 1,500 adults. These estimates assume the best possible production from these populations, a condition that probably occurred only rarely. The smallest populations were probably composed of 10 to 100 spawners during periods of poor ocean conditions.

Using Figure 19, we can assign each population a classification according to our conceptual model. All populations to the left of the vertical line had a relatively low probability of persistence and were classified as Dependent (non-viable *sensu* McElhaney et. al 2000). Their long-term existence depended on input from larger, neighboring populations. Populations to the right of the vertical line were capable of persistence over longer periods. The populations above the horizontal line were considered Functionally Independent, with demographics not greatly influenced by neighboring populations. Those persistent populations below the horizontal line were classified Potentially Independent, capable of sustaining themselves without input from neighboring populations, but with demographics influenced by their larger neighbors. Populations in the upper-left quadrant would be both isolated from other populations and unlikely to persist over a time frame of 100 years. These could be considered ephemeral populations. Such populations would experience periodic extinctions with low probability of

recolonization from other populations. None of our historical populations fell into this category. This lends some support to the break points we chose for the horizontal and vertical lines.

Forty-eight (slightly over 70%) of the 67 populations we identified were classified as Dependent populations. Altogether they inhabited less than 6% of the coho salmon habitat in the Oregon Coast Salmon ESU. Based on our models, these populations probably would have experienced periodic extinction and recolonization events on a time frame of 10 to 1000 years. There is a wide range of basins in this category, ranging from Twomile Creek, supporting up to 13,000 adults at 10% marine survival, to Indian Creek, Red Rock Creek, and Squaw Creek, each estimated to produce only 10 adults under good marine survival. The larger dependent populations are expected to be occupied most of the time, while many of the smaller systems probably do not have spawning coho in most years. Some of the smaller systems we have identified may never have supported coho, while there may be other small systems not on our list where coho occasionally spawn.

Figure 21 is a map of proposed populations and Table 7 is the list of populations and their proposed classification. Table 8 allows a comparison between population classification and the distance to the nearest Functionally Independent population. Ten of the 67 populations were classified as Functionally Independent, including the two in the Umpqua Basin. An additional nine populations were classified as Potentially Independent, including the populations in the three large lake basins and the Coos Basin. The Coos population is a good illustration of the distinction between Functionally and Potentially Independent populations. Although this is the sixth largest historical population on the coast, it is flanked by the two largest; the Umpqua Basin (here treated as a single population) to the north and the Coquille to the south. These two large populations would have provided enough adult migrants into the Coos Basin to affect its demographics, even though the Coos is certainly large enough to sustain itself in the absence of input from other populations. It must be remembered that these classifications are for historical populations, and do not reflect the current functioning of this ESU.

Forty-eight (slightly over 70%) of the 67 populations we identified were classified as Dependent populations. Altogether they contained less than 6% of the coho salmon habitat in the Oregon Coast Coho Salmon ESU. Based on our models, these populations probably would have experienced periodic extinction and recolonization events on a time frame of 100 to 1000 years.
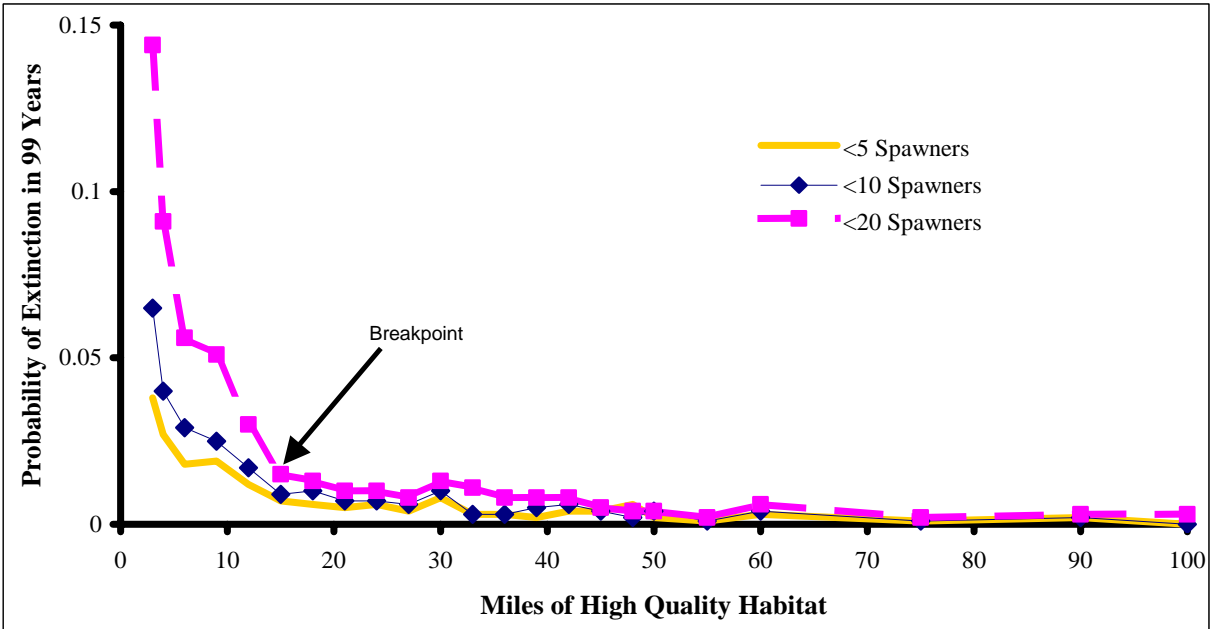
Figure 20. The relationship between the quantity of high-quality habitat (habitat that will support populations of coho salmon when marine survival is 3%) and probability of extinction defined as the number of spawners less than 5, 10, or 20 (from Nickelson 2001).
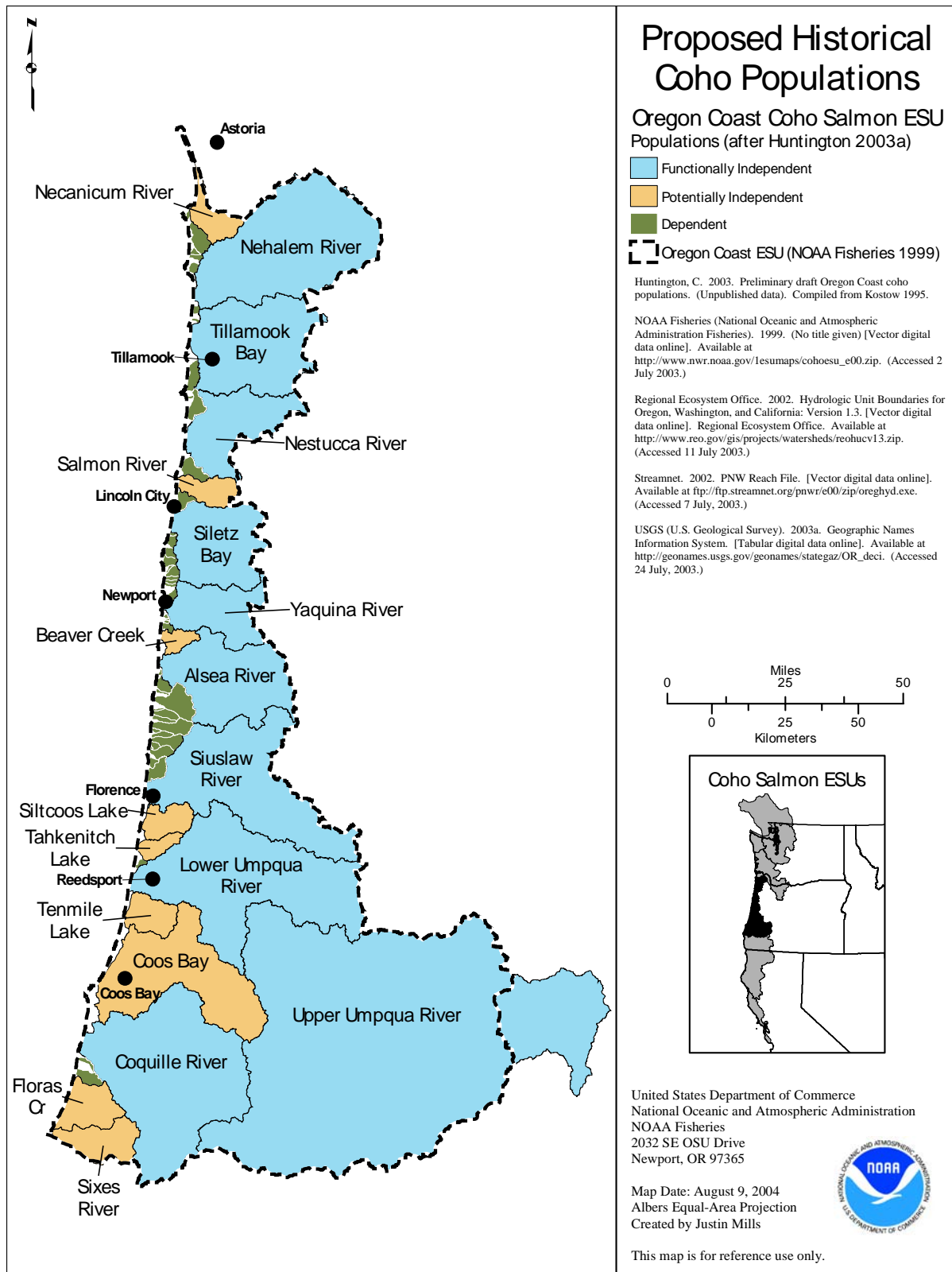
Figure 21.   Proposed historical coho populations in the Oregon Coast Coho Salmon ESU. Dependent-population basins are identified in Figure 3.

Table 7.   Proposed historical populations, listed north-to-south, with classification (App. III, Bjorkstedt 2004).

Population	Population type	Population	Population type
Necanicum R.	Potentially Independent	Moore Cr.	Dependent
Indian Cr.	Dependent	Theil Cr.	Dependent
Canyon Cr.	Dependent	Beaver Cr.	Potentially Independent
Ecola Cr.	Dependent	Alsea R.	Functionally Independent
Red Rock Cr.	Dependent	Little Cr.	Dependent
Austin Cr.	Dependent	Big Cr.	Dependent
Asbury Cr.	Dependent	Vingie Cr.	Dependent
Arch Cape Cr.	Dependent	Yachats R.	Dependent
Short Sand Cr.	Dependent	Gwynn Cr.	Dependent
Nehalem R.	Functionally Independent	Cummins Cr	Dependent
Spring Cr.	Dependent	Bob Cr.	Dependent
Watseco Cr.	Dependent	Tenmile Cr.	Dependent
Tillamook Bay	Functionally Independent	Squaw Cr.	Dependent
Netarts Bay	Dependent	Rock Cr.	Dependent
Rover Cr.	Dependent	Big Cr.	Dependent
Sand Cr.	Dependent	China Cr.	Dependent
Nestucca R.	Functionally Independent	Blowout Cr.	Dependent
Neskowin Cr.	Dependent	Cape Cr.	Dependent
Salmon R.	Potentially Independent	Berry Cr.	Dependent
Devils Lake (lake)	Dependent	Sutton Cr. (Mercer Lake)	Dependent
Siletz R.	Functionally Independent	Siuslaw R.	Functionally Independent
Schoolhouse Cr.	Dependent	Siltcoos R. (lake)	Potentially Independent
Fogarty Cr.	Dependent	Tahkenitch Cr. (lake)	Potentially Independent
Depoe Bay Cr.	Dependent	Threemile Cr.	Dependent
Rocky Cr.	Dependent	Lower Umpqua	Functionally Independent
Johnson Cr.	Dependent	Upper Umpqua	Functionally Independent
Spencer Cr.	Dependent	Tenmile Cr. (lake)	Potentially Independent
Wade Cr.	Dependent	Coos Bay	Potentially Independent
Coal Cr.	Dependent	Coquille R.	Functionally Independent
Moolack Cr.	Dependent	Johnson Cr.	Dependent
Big Cr.	Dependent	Twomile Cr.	Dependent
Yaquina R.	Functionally Independent	Floras Cr.	Potentially Independent
Henderson Cr.	Dependent	Sixes R.	Potentially Independent
Grant Cr.	Dependent		

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Table 8. Locations of river mouths and distance to the nearest Functionally Independent population for basins along the Oregon Coast (Kilgour 2003)[a].

Basin Name	Latitude	Longitude	Population Type[b]	Distance (km) from Columbia River	Distance (km) to Nearest FI Population
Columbia	46.244	124.057	N/A	0.0	--
Necanicum	46.012	123.926	PI	27.7	40.7
Indian	45.9307	123.9781	D	37.6	30.8
Canyon	45.9304	123.9779	D	37.6	30.8
Ecola	45.8993	123.9625	D	41.2	27.2
Red Rock	45.845	123.961	D	47.3	21.1
Austin	45.819	123.964	D	50.2	18.2
Asbury	45.815	123.962	D	50.6	17.8
Arch Cape	45.804	123.966	D	51.9	16.5
Short Sands	45.76	123.963	D	56.8	11.6
Nehalem	45.658	123.933	FI	68.4	0.0
Spring	45.62	123.937	D	72.6	4.2
Watseco	45.589	123.984	D	77.6	9.2
Tillamook	45.488	123.901	FI	90.5	0.0
Netarts	45.403	123.944	D	100.6	9.9
Rover	45.328	123.967	D	109.1	18.6
Sand	45.29	123.937	D	113.9	23.4
Nestucca	45.184	123.956	FI	125.8	0.0
Neskowin	45.1	123.986	D	135.4	9.6
Salmon	45.047	124.005	PI	141.5	15.7
Devils Lake	44.968	124.016	D	150.3	7.1
Siletz	44.904	124.01	FI	157.4	0.0
Schoolhouse	44.873	124.041	D	161.6	4.2
Fogarty	44.839	124.053	D	165.5	8.1
Depoe	44.806	124.058	D	169.2	11.8
Rocky	44.779	124.071	D	172.4	15.0
Johnson	44.738	124.059	D	177.0	14.9
Spencer	44.729	124.059	D	178.0	13.9
Wade	44.716	124.06	D	179.5	12.4
Coal	44.708	124.061	D	180.4	11.5
Moolack	44.703	124.063	D	180.9	11.0
Big Creek (near Yaquina)	44.659	124.058	D	185.8	6.1
Yaquina	44.613	124.017	FI	191.9	0.0
Henderson	44.589	124.068	D	196.7	4.8
Grant	44.581	124.068	D	197.6	5.7
Moore	44.572	124.069	D	198.6	6.7

[a] Columbia and Elk rivers are included to locate the ESU boundary. Tributaries to Tillamook Bay are assumed to harbor a single population.
[b] D = Dependent; FI = Functionally Independent; PI = Potentially Independent

Table 8 continued. Locations of river mouths and distance to the nearest Functionally Independent population for basins along the Oregon Coast (Kilgour 2003).

Basin Name	Latitude	Longitude	Population Type	Distance (km) from Columbia River	Distance (km) to Nearest FI Population
Thiel	44.565	124.07	D	199.4	7.5
Beaver	44.524	124.075	PI	204.0	11.0
Alsea	44.423	124.08	FI	215.2	0.0
Little	44.393	124.088	D	218.6	3.4
Big Creak (near Alsea	44.371	124.088	D	221.0	5.8
Vingie	44.341	124.098	D	224.5	9.3
Yachats	44.309	124.107	D	228.1	12.9
Gwynn	44.271	124.11	D	232.3	17.1
Cummins	44.266	124.108	D	232.9	17.7
Bob	44.244	124.11	D	235.3	20.1
Tenmile	44.226	124.11	D	237.3	22.1
Squaw	44.2086	124.1133	D	239.3	21.4
Rock	44.183	124.114	D	242.1	18.6
Big Creek (near Suislaw)	44.177	124.114	D	242.8	17.9
China	44.169	124.115	D	243.7	17.0
Blowout	44.157	124.117	D	245.0	15.7
Cape	44.134	124.123	D	247.6	13.1
Berry	44.095	124.122	D	251.9	8.8
Sutton (Lake)	44.06	124.127	D	255.9	4.8
Siuslaw	44.017	124.136	FI	260.7	0.0
Siltcoos (Lake)	43.874	124.153	PI	276.6	15.9
Tahkenitch (Lake)	43.815	124.165	PI	283.3	16.5
Threemile	43.748	124.18	D	290.8	9.0
Umpqua	43.669	124.204	FI	299.8	0.0
Tenmile (Lake)	43.562	124.231	PI	311.9	12.1
Coos	43.429	124.229	PI	326.6	37.6
Coquille	43.124	124.429	FI	364.2	0.0
Johnson	43.093	124.431	D	367.6	3.4
Twomile	43.044	124.441	D	373.1	8.9
Floras	42.913	124.496	PI	388.3	24.1
Sixes	42.854	124.543	PI	395.9	31.7
Elk	42.81	124.533	N/A	400.9	--

[a] Columbia and Elk rivers are included to locate the ESU boundary. Tributaries to Tillamook Bay are assumed to harbor a single population.
[b] D = Dependent; FI = Functionally Independent; PI = Potentially Independent

DISCUSSION

Our view of the historical population structure of Oregon Coast coho salmon relies upon a simple conceptual model of the spatially-dependent demographics of 67 populations we consider likely to have been present within the ESU. This model classifies populations on the basis of two key characteristics: persistence (their relative abilities to persist in isolation from one another) and isolation (the relative degree to which they might have been influenced by adult fish from other populations straying into their spawning areas). The interaction of these two factors across what we believe to have been the historical populations of Oregon Coast coho salmon gives us a measure of Relative Independence.

Our model of the interplay between the persistence and isolation of historical coho populations within the Oregon Coast ESU provided us a clear method for classifying the relative independence of individual populations. Historical populations were classified into three distinct groups: Functionally Independent, Potentially Independent, and Dependent. In general, Oregon Coast drainage basins of intermediate to large size (whose coho populations fell to the right of a persistence threshold in Figure 19) are thought to have each supported a coho population capable of persisting indefinitely in isolation, though some of them (seen below a horizontal line representing an isolation threshold in Figure 19) may have been demographically influenced by adult coho straying into spawning areas from elsewhere in the ESU. Those persistent populations with minimal demographic influence from adjacent populations were classified as Functionally Independent (9 populations), while populations that appeared likely to have been capable of persisting in isolation but were demographically influenced by adjacent populations were classified as Potentially Independent (9 populations). Small coho populations would have been found in 48 smaller coastal basins (seen falling both to the left of the persistence line and below the isolation line in Figure 19) and may not have been able to maintain themselves continuously for periods as long as hundreds of years without the demographic boost provided by migrating spawners from other populations. For this reason, these populations were classified as Dependent.

We believe that the Dependent populations relied at times upon the strength of adjacent larger populations for their continuous historical presence in the Oregon Coast's smaller basins. As long as the larger persistent populations within the ESU remained strong, the smaller (Dependent) populations would rarely if ever have disappeared from their basins. However, if some form of broad-scale environmental change triggered a substantial decline in one or more of the larger populations, the reduction in migrants would have increased the possibility that the same environmental change, perhaps coupled with local disturbances, would have resulted in the intermittent disappearances of the Dependent populations found in some of the smaller basins.

Uncertainties

Despite the simplicity of the conceptual model we used to classify the Relative Independence of historical coho populations within the Oregon Coast Coho Salmon ESU, it should be emphasized that analytical components of our model are no different from those of other mathematical models of populations or habitat. Our model produces results that we

consider a reasonable but uncertain approximation of an imperfectly understood biological phenomenon: the interactions of historical Oregon Coast coho salmon populations.

We are confident in the way our modeling has arrayed 67 historical populations of Oregon Coast coho salmon on the basis of their potential abundance. The abundance levels assigned to the populations reflect what is known about how the species uses its habitat and are consistent with patterns evident in both recent and historical data on coho abundance. However, the specific coho population size we used to define our persistence (threshold) line in Figure 19 was based on results from a simple habitat-based model of coastal coho populations developed by Nickelson and Lawson (1998). That model fits data on the recent performance of Oregon Coast coho salmon populations, but habitat available to these populations has been substantially altered from that which supported historical populations, and is of lower quality (IMST 2002). Historical habitats may have been somewhat more stable and productive than those we can study today, raising the possibility that historical coho populations may have been able to persist on smaller quantities of relatively higher quality habitat than recent data on coho abundance and population performance might suggest. There are also inherent between-basin differences in the stability or aggregate productivity of coho habitat that could affect the persistence of some smaller populations but that were only weakly accounted for when we used absolute coho abundance as a proxy for population persistence. Taking these things into account, we assessed the sensitivity of our population classifications to a 50% reduction in the coho population size used as a persistence threshold and found that only 5 of 49 coho populations otherwise classified as Dependent (Twomile Creek, Sand Lake, Devils Lake, Sutton Lake, and Yachats River) would be reclassified as Potentially Independent. Similarly, a 50% increase in the persistence threshold would have resulted in only one Potentially Independent population (Salmon River) being reclassified as Dependent. Most of our classifications of populations would thus be unaffected by what we might consider as reasonable changes to our persistence threshold.

Another area of uncertainty within our classification model is the dispersal pattern used to simulate migration between coho populations, and thus to distinguish between Functionally Independent and Potentially Independent populations in the historical ESU. The pattern that we used assumes an exponential decline in migration rate with increasing distance from the natal basin and does not account for a variety of environmental gradients that may (or may not) affect the relative attractiveness of non-natal basins to straying coho. A more complex pattern might be more realistic, but we are not aware of any data or studies that would provide us a sufficient basis for structuring such a pattern. This creates uncertainty about the degree to which the results of our model reflect the true isolation of individual coho populations. Sensitivity analyses by Bjorkstedt (2004) have shown that changes in the assumed dispersal pattern of migrant coho tend to have only minor effects on the apparent isolation of the larger coho populations within the historical Oregon Coast Coho Salmon ESU, but variable effects on the apparent Isolation of intermediate-sized to smaller populations. This is a topic worthy of further investigation.

Other Applications of the Relative Independence Model

Our model-based approach to classifying the Relative Independence of coho salmon populations within the Oregon Coast Coho Salmon ESU may be of interest to other NOAA Fisheries Technical Recovery Teams because it provides a structured way to delineate

independent salmon populations within geographically linked coastal areas. At present, the general model is being used to help identify historically independent coho salmon populations within two additional ESUs, both along the California coast. The model may also prove useful in examining recent changes in the interactive demographic behavior of geographically linked salmon populations and in establishing a conceptual framework for the development of ESU recovery goals.